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DELAWARE RIVER BASIN REPORT

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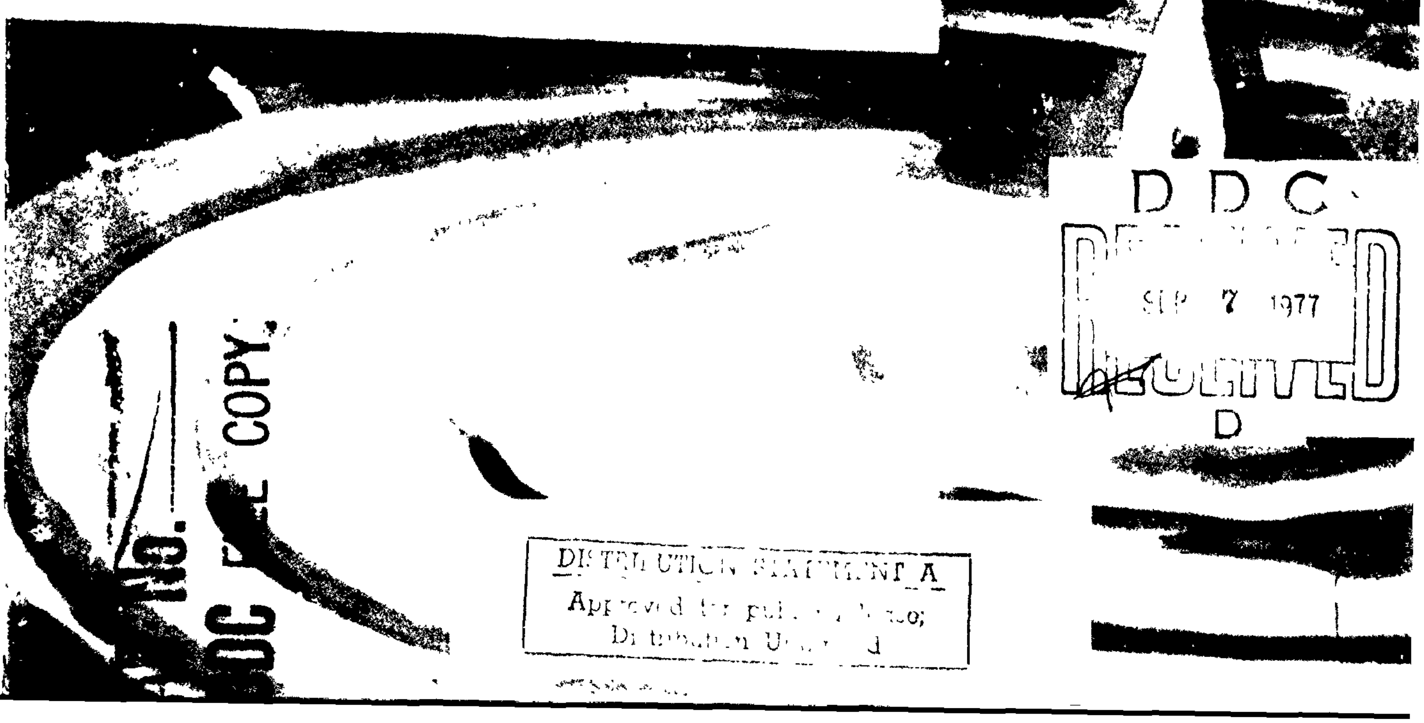
APPENDIX O. STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY



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REPORT ON THE

COMPREHENSIVE SURVEY

OF THE

WATER RESOURCES

OF THE

DELAWARE RIVER BASIN.

Volume - VIII.

APPENDIX O.

STATE OF DELAWARE

INTRASTATE WATER RESOURCES SURVEY,

58p

PREPARED BY

THE STATE OF DELAWARE COORDINATORS
IN COOPERATION WITH VARIOUS STATE INTERESTS

AND FURNISHED TO

U. S. ARMY ENGINEER DISTRICT, PHILADELPHIA
CORPS OF ENGINEERS
PHILADELPHIA, PA.

LETTER OF TRANSMITTAL

Dover, Delaware
September 8, 1959

Colonel T. H. Setliffe, District Engineer
U.S. Army Engineer District, Philadelphia
Corps of Engineers
Philadelphia 29, Pennsylvania

Dear Colonel Setliffe:

Transmitted herewith is the report entitled, "State of Delaware - Intrastate Water Resources Survey." A knowledge and understanding of our State will be considerably increased by the detailed review which has been prepared by the Delaware State Coordinators who represent the State of Delaware on the Delaware River Basin Survey Committee. This document deserves the most careful study by every member of the Committee and the Federal agencies participating in the survey, and I hope each of them will take the time to familiarize himself with its contents.

This report, the fruit of almost three years of intensive study by experts of the State, including various governmental agencies of Delaware, shows that in the past decade the State of Delaware has intensified its agricultural practices and is rapidly changing in certain areas to an industrial State. The report indicates that our water needs are changing rapidly, and we face a serious water crisis in the not-too-distant future.

This report throughout points to the expected growth of the State and the need for water which must be obtained if our economic progress is to continue to the year 2060.

I am confident that the Corps of Engineers and the various Federal agencies cooperating with them will make a detailed study of the report and give full and proper consideration of our State's requirements.

The study cannot end with the publication of the reports. Continued effort will be needed to solve the water problems. I realize as the need arises legislation will be required to cope with the various problems.

It is my hope that this report and others by the Corps of Engineers and the Federal agencies will result in action which will contribute significantly to the improvement and continued growth of the Delaware River Basin Area and the State of Delaware.

Sincerely,

J Caleb Boggs

J. Caleb Boggs
Governor
State of Delaware

LETTER OF TRANSMITTAL

Dover, Delaware, August 13, 1959

Honorable J. Caleb Boggs
Governor of Delaware
Dover, Delaware

Dear Governor Boggs:

Transmitted herewith is the "State of Delaware Intrastate Report on the Delaware River Basin Survey" as prepared by the Delaware State Coordinators and concerning the basin water resources problems as they affect Delaware.

This report is offered as the State of Delaware's Appendix to the overall Corps of Engineers' "Report on the Comprehensive Survey of the Water Resources of the Delaware River Basin."

This document deserves the most careful study by the people of Delaware and their officials, and it is hoped that many will take the time to become familiar with its contents. Your attention is requested especially to the Synopsis, Summary Observations, Recommendations, and Discussion sections.

This report, the result of almost three years of effort by the Coordinators, State agencies, County agencies and other interested organizations who participated, shows that the State of Delaware has changed in many ways over the past decade and indicates even greater changes which will affect every citizen in the future.

This report underlines the fact that Delaware will be deficient in available water supply to meet its needs long before the year 2010. The outlook for the future development of the State is not encouraging unless the people of the State, by their own efforts, utilize to the best advantage the available water, but in any case water must be obtained beyond the boundaries of the State. Unless water resources can be made secure, the major problem in the State will not be highways, nor education, nor agriculture, nor forests, nor industry, nor any other phase of our day-to-day activities, but the availability of water.

This report is submitted as the first comprehensive study of Delaware's water problem and its relation to the activities of the people

Honorable J. Caleb Boggs
Page 2
August 13, 1959

I should like to call your special attention to the work of Dr. A. Jcel Kaplovsky, Alternate State Coordinator, and Mr. Chauncey O. Simpson, Alternate State Coordinator. The bulk of this report can be attributed to the interests and efforts of these two men. The Deputy State Coordinator, Richard A. Haber, has acted in a review capacity, and it has taken the combined efforts of these and others listed in the acknowledgment section to produce this comprehensive report which it is hoped will contribute significantly to the future of the State of Delaware.

Respectfully submitted,

Gordon Smith

J. Gordon Smith
State Coordinator
Delaware River Basin Water
Resources Survey

STATE OF DELAWARE

INTRASTATE WATER RESOURCES SURVEY

PREPARED FOR

THE CORPS OF ENGINEERS

U.S. ARMY ENGINEER DISTRICT

PHILADELPHIA, PA.

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PREFACE

A long-awaited need is being met in a broad, comprehensive survey of the water resources of the Delaware River and related problems covering a period of 50 and 100 years hence. Past practices of planning less than 50 or 100 years has been proven to lack sufficient comprehensiveness to encompass the multitude of problems related to water supply, recreation, waste disposal, navigation, growth and development within the Delaware Valley and its adjacent service area.

This nation has grown from an agricultural to an industrial nation of which the Delaware Valley and its service area is a part. In reality 50 or 100 years is not a very long period of time. In fact, are we not considering an interval of time during which our children and grandchildren must be affected? Man may now reminisce upon his own life of 50 or more years and is it not equally realistic to project similarly into the future? In essence, man's life span covers the better part of a century.

Of prime importance is water; man can survive without food more easily than without water. What is true of the individual is true of his civilization. History has proven that civilizations perish, dwindle, or migrate because of lack of water, which in most instances occurs when the demand exceeds the supply. This circumstance does not happen all at once, but is in nature a slow process; however, if the impending disaster is evaluated and provided for, the loss of growth and development can be prevented.

The most difficult undertaking in planning for the future is to make the people extend their thinking to the future and not entangle their thoughts excessively with the present. It is human nature on discussing potential problems and needs 25, 50, and 100 years hence, that one immediately projects its effect inwardly into his present habitat and not outwardly for the future. When projecting 50 years hence at the rate of growth and development and water usage of the immediate past 20 years, the change will appear monumental indeed. Even if these future projections were to take place at half the rates of growth and development of the past 20 years, the comparative change with the present will still appear surprisingly large to many.

At first glance the task ahead appears overwhelming. However, in the past several years it has become increasingly evident that many of the initial problems are soluble if sufficient effort and foresight are placed into such a survey. All planning must exceed all past efforts which in many instances have been conservative or incomplete so that results have fallen short of requirements.

Lest we forget - the water resources problems of the future loom large indeed. We must aim to provide for unseen generations. If we persist at conservatism, our efforts will not achieve the needs we strive for. We must plan broadly so that it is possible to achieve our goals.

ACKNOWLEDGMENTS

The preparation of a comprehensive intrastate report involves sifting and assembling a large mass of details. In order to do this, it was necessary to have the advice and cooperation of many individuals. The cooperation has been given generously on the part of many individuals, governmental agencies, and industrial corporations.

The Coordinators wish to express their grateful appreciation to the following individuals who contributed reports used in the preparation of this Appendix to the Corps of Engineers Report on the Delaware River Basin Water Resources Survey, without which the Coordinators could not have made this compilation:

Mr. Leon de Valinger, Jr., State Archivist, Public Archives Commission, for the report "Conservation of Cultural Resources."

Dr. George M. Worrilow, Dean and Director of the School of Agriculture, University of Delaware, and Mr. E.H. Talbert, State Drainage Engineer, for the report of the State Soil Conservation Commission.

Dr. Paul Bock, Associate Professor of the Civil Engineering Department, University of Delaware, for the report "Surface Water Supplies of Northern Delaware."

Mr. William S. Taber, State Forester, State Forestry Department, for the report on State Forests.

Dr. Jay L. Harmic, Federal Aid Coordinator, for the report of the Board of Game and Fish Commissioners.

Dr. Johan J. Groot, State Geologist, for the Delaware Geological Survey, University of Delaware.

Mr. Donald K. Harmeson, Director of the Division of Sanitary Engineering, State Board of Health, for the report of the State Board of Health on Public Water Supply.

Mr. Vohnnie L. Pearson, Assistant Bridge Engineer, State Highway Department, for the report "Beach Areas as Future Population Generators."

Mr. David K. Witheford, Planning Engineer, State Highway Department, for the report "Effect of Transportation on Population Growth in Delaware."

Dr. Carl N. Shuster, Jr., Director of the University of Delaware Marine Laboratories, for the report "Biological Evaluation of the Delaware River Estuary."

Mr. Pete[illegible] eldof, Superintendent of State Parks, for the report of the State P[illegible] Commission.

Mr. Albert Stetser, Chairman and Executive Director, Delaware Unemployment Compensation Commission, for the report "With the Establishment of New Industries in the State, What will be the Availability of Labor in the Future?"

Dr. A. Joel Kaplovsky, Director of the Water Pollution Commission, for the two reports on pollution aspects and the quality studies of the Delaware River Estuary.

Mr. F. Alton Tybout, Chief Deputy Attorney General, for information contained in Section XXVIII entitled "Legal Aspects."

The Coordinators are indebted to the large number of specialists who actively cooperated in the initial stage of the survey by supplying informative letters which helped formulate the course of the report:

Mr. Peter Geldof, Jr., State Park Commission, Dean M. Worrilow, School of Agriculture, University of Delaware; Mr. George Winchester of Laird, Bissell and Meeds; Mr. Fred S. Price, Engineer-Director, Regional Planning Commission of New Castle County; Mr. William S. Taber, State Forestry Department; Colonel C.B. Shaffer, Delaware State Development Department; Mr. George T. Bierlin, Public Service Commission; Mr. J. Huber Denn, Delaware State Chamber of Commerce, Inc; Dr. Floyd I. Hudson, State Board of Health; Mr. Cecil A. Marshall, State Board of Health; Mr. W. Compton Wills, Wilmington Water Department; Dr. Johan J. Groot, State Geologist, Delaware Geological Survey; Dr. Jay I. Harmic, Board of Game and Fish Commissioners; Mr. Otis H. Smith, Fish Products Company; Mr. Nathaniel W. Taylor, Jr., Delaware Commission of Shell Fisheries; Mr. Albert Stetser, Unemployment Compensation Commission; Mr. John I. Cahalan, County Engineer for the New Castle County Levy Court; and Mr. John L. Clough, State Board of Agriculture.

Special thanks is due to those who participated for the State of Delaware at the Hearing on the Barrier Dam held in Wilmington.

Governor J. Caleb Boggs, Governor of Delaware; Mr. Richard A. Haber, Chief Engineer, State Highway Department and State Coordinator; Dr. A. Joel Kaplovsky, Director for the Water Pollution Commission and Alternate State Coordinator; Mr. Joe S. Robinson, Assistant Chief Engineer, State Highway Department; Dr. Floyd I. Hudson, Executive Secretary of the State Board of Health; Mr. Norman Wilder, Director of Conservation, Board of Game and Fish Commissioners; Mr. Eden F. Jones, Field representative of the Public Service Commission; Mr. E.H. Talbert, Drainage Engineer of the Soil Conservation Commission; Dr. Paul Bock, Associate Professor, Civil Engineering Department of the University of Delaware; Dr. Johan J. Groot, State Geologist, Delaware Geological Survey; Dr. Carl N. Shuster, Jr., Director of the University of Delaware Marine Laboratories; Mr Nathaniel W. Taylor, Delaware Commission of Shell Fisheries; Mr. W. [illegible]mpton Wills, Chief Engineer for the Board of

Water Commissioners of the City of Wilmington; Mr. Clarence Moore, New Castle County Water Resources Committee, Delaware State Chamber of Commerce; Brigadier General Norman M. Lack, Delaware River Basin Advisory Committee, member of Governor Boggs' Water Study Committee and also of the Commission of Interstate Cooperation.

The Coordinators are grateful to the following individuals who generously gave their time to review Federal reports on agriculture, forestry, irrigation, fish and wildlife, recreational resources, multipurpose reservoirs, municipal and industrial water use, hydrology of the Delaware River and geology distributed by the Corps of Engineers:

Mr. William S. Taber, State Forester; Dr. Jay L. Harmic and Mr. Norman Wilder of the Board of Game and Fish Commissioners; Mr. Peter Geldof, Superintendent of State Parks; Mr. W. Compton Wills, Chief Engineer of the Wilmington Water Department; Colonel C. B. Shaffer of the State Development Department; Mr. John Taylor, County Engineer of the New Castle County Levy Court; Mr. Leon de Valinger, Jr., State Archivist; Dr. Johan J. Groot, State Geologist; Dean George Worrilow, Director of the School of Agriculture, University of Delaware; Mr. E. H. Talbert, State Drainage Engineer, Soil Conservation Commission; Dr. Paul Bock, Civil Engineering Department of the University of Delaware.

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Charles D. Murphy, Mosquito Control Division, State Highway Department; Mr. Herbert L. Keene, Chief Right-of-Way Agent, State Highway Department; Mr. David A. McCue, Suburban Development Engineer, State Highway Department; Professor Thomas W. Brockenbrough, Civil Engineering Department, University of Delaware; Mr. William S. Price, Division Engineer, Bureau of Public Roads.

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Colonel T. H. Setliffe, District Engineer; Colonel Allen F. Clark, Jr., and Colonel W. F. Powers, former District Engineers; Lt. Colonel Frank A. Gerig, Jr., former Acting District Engineer; Lt. Colonel John C. H. Lee, Jr., formerly of the Philadelphia District; Mr. Russell Morgan, Chief of the Valley Report Group; Mr. V. V. Lisovitch, Assistant Chief of the Valley Report Group, and various staff members.

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SECTION I

GENERAL INTRODUCTION

1.01 THE PAST

The Intrastate Water Resources Survey was devised to determine the water needs of the State of Delaware in the next 50 and 100 years. Before considering the future we must examine the past for the factors which caused us to arrive at the position we now occupy among the states of the Nation. Population will continue to increase due to births alone. It is also evident that certain factors acting as generators of population will bring, in addition, an influx of people from outside the State. The birth rate has increased in the United States beyond all expectations of forecasts made years ago. The eastern part of the United States is the oldest portion of the country and the most developed in all phases of manufacturing and trades. Delaware, due to its geographical location, along with its neighboring states, has received an influx of population from other areas.

With the growth of the United States the geographical center of population has moved steadily westward. In 1790 it was thirteen miles east of Baltimore, Maryland; in 1800, eighteen miles west of Baltimore; in 1850, twenty-three miles southeast of Parkersville, West Virginia; in 1900, six miles southeast of Columbus, Indiana; and in 1950, eight miles northwest of Olney, Illinois. Northern Delaware is in the core area of the United States which extends from the Atlantic Ocean on the east to Nebraska on the west, and from the Ohio River on the south to the Great Lakes and Erie Canal on the north. Within this area, which approximates 14 percent of the total area of the United States, is contained approximately 50 percent of the United States' population.

Examination of a map of the eastern portion of the United States reveals that former towns, now cities, such as Baltimore, Wilmington, Philadelphia, and Trenton, are located on rivers at the approximate location of the tidal reach. As colonization extended westward beyond these locations the concentration of water transportation facilities remained at these sites and the earlier coastal settlements lost their importance. Later roads were constructed between the coastal towns and those inland so that the area between began to fill with new towns, thus completing the colonization of the coastal region.

It must be remembered that early industries depended on water power, which could be obtained in sufficient quantities only in the reaches of the stream beyond the coastal plain. The New England states had an abundance of water power due to the geographical formation of the area, as many of the small streams run directly into the ocean and the terrain is of such nature that the tidal reach extends only a short distance from the ocean.

A map of the eastern seaboard clearly shows that from Washington northward to Boston the towns mentioned above are located on the Fall Line, west of which lies the Piedmont Plateau and eastward the Coastal Plain. South of Washington the mountains swing westerly. Those land areas within the Coastal Plain, of which lower Delaware is a part, remained primarily agricultural. Locations at the Fall Line soon developed into industrial sites due to the water power available and the ease for ocean shipping to reach these points. Northern New Castle County is in this area and its population has outstripped the rest of the State. The manufacturing centers acted as generators of population.

It follows that later in the 19th century, due to the lack of roads, railroads were constructed to connect the towns along the eastern seaboard. As a result, towns located at the intersections of the railroads and at the head of tidal reaches became dense population centers. Many immigrants arriving at these ports of entry found employment and chose to stay instead of going westward.

The climate of the eastern seaboard from Washington northward through Massachusetts also was favorable to industry. Wilmington, in New Castle County, meets all these requirements. The lower portion of the State being isolated by two rivers and bays was generally inaccessible to adjoining states, hence it is only natural that it has remained primarily agricultural, similar to much of New Jersey, except for the early shipbuilding industry, which occurred at the tidal heads of the various creeks and streams in the lower counties.

The population pattern of Delaware was well established by the middle of the 19th century. The population growth of the State continued at a low rate until about 1890 when there was a slight upturn. Before this date the West was largely unsettled; however the frontier was rapidly closing. Sparsely occupied lands were being filled by the influx of settlers and choice lands close to the railroads were no longer available. In Delaware the rate of increase of population remained rather constant until just before the middle of the 20th century. The World War II demand for labor in the industrial areas was at an all-time high, thus attracting people from the agricultural areas.

Farms were becoming smaller as the result of dividing the land among the children of a family. In many cases the farms became so small that further division could not occur economically. As a result, the surplus of population in agricultural areas looked to the industrial areas for work. With improved mechanization of the farm fewer people were needed on the farms, another factor which augmented migration. Many of those who came to the metropolitan areas during the war remained permanently. Industrial plants were expanding to produce new products to meet the demands to maintain improved American living standards.

The children of the 1930's are now of the age to have families of their own. Life is more secure, so families are larger. Large families in the early 19th century were necessary to operate the farms, but today large families are common to both the farm and the city.

1.02 THE PRESENT

As a result of these conditions which fostered an increased population, the eastern seaboard from the Potomac River to Cape Cod continues to be the most rapidly expanding portion of the United States.

Northern Delaware is now in the industrial center of the eastern United States. Other ports along the coast are being pressed for available port space. Delaware is one of the locations on the eastern termini of the new Federal interstate system of controlled roads. Northern New Castle County is on the north-south route of two major railroads connecting the large cities of the east to cities of the west. Northern Delaware is between the Capital of the United States and the largest city in North America. Delaware also is the home of large chemical industries which are expanding rapidly. All these factors act as population generators which increase the rates of population growth. This has been evident over the recent years.

1.03 THE FUTURE

The big problem which faces this state today with regard to its future is the expected growth of industry and its accompanying need for increased water supply. In order to meet projected growth it must be assumed that there will be sufficient water available.

Population growth depends not only on biologic and economic factors but upon the availability of natural resources. Water is the most important natural resource, and failure of the supply may be the determining factor in the future growth of the State. Early civilizations have moved or declined because of a lack of water to support a vigorous population.

Due to the large amount of established industry in New Castle County, the result of earlier factors which set the pattern which exists today, it must be assumed that water will continue to be available, and if such be the case, industrial development will be a major controlling factor for the future. Due to the changes occurring in agricultural practices irrigation is becoming an accepted practice in the east, and we must recognize that it will play a vital part in the future in its competition for water. It is vital that the State protect its interests in its water rights to the utmost.

Future water requirements must be determined and it is conceivable that the State may have to obtain water from sources outside of its boundaries. Countries where land use has changed from agricultural to industrial are the most prosperous and maintain the highest standard of living. When the future supply of water becomes limited, progressive growth within the State will cease.

With this expected development we must also bear in mind that land use should be planned and guided if the State is to continue being a fit place in which to live. Precautions must be exercised to preserve as much as possible of those benefits which the present population now enjoys but does not realize. An ounce of prevention is worth a pound of cure. Many

of the benefits we now enjoy, or which make life easier, can never be replaced once they are lost.

1.04 REASONS FOR THE "REPORT ON THE COMPREHENSIVE SURVEY OF THE WATER RESOURCES OF THE DELAWARE RIVER BASIN"

The surging momentum of hurricanes Connie and Diane in August 1955, which claimed 100 lives and caused damage estimated to be over $100 million, strikingly supplied the impetus needed for initiating a comprehensive water resources survey of the Delaware River Basin. Studies have been made by the Corps of Engineers, Incodel, and others, but a major disaster was needed to emphasize sufficiently the problems facing the residents of the Delaware River Valley and Service Area.

A series of resolutions and emergency supplemental appropriations to make specific surveys and studies closely followed these disastrous floods. It was not until October 22, 1956, that a summary plan of approach was consummated. The President of the United States on this day wrote a letter requesting the Department of the Army to exercise particular care throughout the survey and, in the preparation of the survey report, to solicit and take into account the comments and views of the Federal agencies and the affected states and municipalities. The President directed that arrangements and procedures be established which will assure a full and continuing exchange of views and information among the parties concerned. The President's letter also directed that every effort be made to utilize the technical resources of the Federal agencies and the States and local governments in the assembly and evaluation of data pertinent to the comprehensive survey.

A draft of the procedural plan of survey was published on November 8, 1956, by the Army Engineer District, Philadelphia. This plan outlined the various phases to be undertaken in the investigation and the cooperative studies to be developed by the Federal agencies, the several states, and other local agencies. This plan further specified that the Army Engineer District, Philadelphia, will assemble pertinent data from all known sources and analyze existing reports relative to the Delaware River and its tributaries. Reports included in this analysis will include those made by Federal agencies, by state and local agencies, and by private firms. Further, preparation of the Report on the Comprehensive Survey of the Water Resources of the Delaware River Basin is the responsibility of the District Engineer of the Philadelphia District and includes the coordination of the studies and investigations made by the cooperating agencies. This report and the appendix will be published by the U.S. Army Engineer District, Philadelphia.

1.05 REASONS FOR THE "INTRASTATE WATER RESOURCES SURVEY"

The State of Delaware, when invited to participate in this activity, deemed it appropriate to prepare an Intrastate Water Resources Survey Report as an appendix to the Corps of Engineers water resources survey. This position was taken for two reasons: 1) in order for the State representatives (Coordinators) to fully evaluate the various interim reports prepared by other agencies encompassing problems within the State of

Delaware, a fuller knowledge of Delaware's water resources problems had to be known; and, 2) our governmental structure, consisting of numerous commissions, agencies and interests, is not readily conducive to providing a coordinated state effort with regard to supplying water resources information. Consequently, it was deemed logical and reasonable that the State of Delaware make a concentrated effort to collect and develop water resources information in accordance with the Corps of Engineers Procedural Plan, thereby supplementing and expediting the flow of needed information.

The organization problem within the State of Delaware constituted the collection and coordination of detailed data from 27 different governmental commissions and agencies. The state coordination organization is presented in detail in Section VII.

The need for a concise evaluation of the future problems, prepared in a manner clear to all its readers, became a factor of importance early in the preparation phase of the report. Two alternatives existed: 1) to write a technical type report on each phase of the problem, or 2) to write a general, semitechnical report which can be understood readily by the majority of the readers. Consequently this State report was carefully edited and, whenever possible, was expressed in terms for the lay reader. In conjunction with this approach, a list of references is included in or with each section to substantiate the various general conclusions, observations, and recommendations made herein.

SECTION II - SYNOPSIS

The Corps of Engineers, Philadelphia District, has been charged with the responsibility of preparing a comprehensive survey report of the water resources, related needs, and development within the Delaware River drainage basin and service areas The Corps has undertaken this monumental task and designated the period of consideration to cover the next 50 and 100 years.

The State of Delaware has accepted the responsibility for preparing an intrastate report as an Appendix to the Corps of Engineers Valley Report. This Delaware effort was made to expedite the flow of information needed from this area and to coordinate heretofore uncoordinated intrastate water resources planning.

State interests concerned in any degree with the use of water were requested to contribute data, in report form, relative to present water use, consumptive or non-consumptive, and estimated needs in the years 2010 and 2060. The State Coordinators furnished census-type information on many subjects to assist the participants and to standardize the ground work. Response to this request was quite good, and the various contributions made are incorporated into this report.

Several sections not readily applicable to a specific interest, in addition to Summary Observations, Recommendations, Topography, and Discussion, were prepared by the State Coordinators.

This intrastate report on Delaware's water resources and projected needs is the first state-wide undertaking to cover this important aspect.

SECTION III
SUMMARY OBSERVATIONS

Below are listed salient points observed in the various parts of this report. The statements are expressions by the section authors, as listed in the acknowledgments, and the Coordinators have made no attempt to reconcile conflicting points of view. Many additional interesting and significant observations can be made from the data contained in the various sections of this report.

SECTION V - TOPOGRAPHY OF DELAWARE

1. A total of 54.8 percent of Delaware is tributary to the Delaware Drainage Basin, and the remainder is tributary to the Atlantic Ocean or the Chesapeake Bay.

2. Delaware is situated largely in the Coastal Plain with a small portion, 6 percent, of the extreme north in the Piedmont Plateau.

3. The Brandywine is the only typical mountain stream in Delaware.

4. Excluding the Delaware River, the land and water area of the State totals 2,100 square miles. Of this, approximately 435 square miles are continually subjected to saline water.

5. Many streams in Delaware, particularly in the lower portion, have their origin in swamps and bogs.

6. Drainage is a problem for at least 25 percent of the State. The problem is further complicated by the fact that these poorly drained lands occur in scattered areas. In northern New Castle County the drainage problem is becoming more acute as urbanization increases.

SECTION IX - PUBLIC ARCHIVES COMMISSION CONSERVATION OF CULTURAL RESOURCES

1. The Delaware River Basin has one of the richest historical backgrounds of any section of the country. The State of Delaware has an ample share of this historical background.

SECTION X - GROWTH AND DEVELOPMENT PROJECTIONS

1. During the past 10 years, portions of the State of Delaware have been experiencing an unprecedented rate of growth. This growth rate is among the highest in the Delaware Valley area.

2. The growth rate in the State of Delaware will not proceed at a uniform rate. Kent County will experience the greatest rate of change through 1965. It is anticipated there will be a declining rate of increase after 1965 on through the year 2060 in each of the counties.

3. Projected population shows Delaware as having 631,000 people in 1965; 857,000 in 1980; 1,426,000 in 2010, and 3,352,000 by 2060.

4. Between 1958 and 2010, New Castle County is expected to show a threefold increase in population growth; 3.85 times in Kent County; and 2.74 times in Sussex County.

SECTION XI - STATE HIGHWAY DEPARTMENT PLANNING DIVISION
EFFECT OF TRANSPORTATION ON POPULATION GROWTH IN DELAWARE

1. Excellent transportation facilities exist in the central location of Delaware with respect to the most heavily populated area in the country, as evidenced by the fact that more than 50,000,000 people may be served with Delaware's products within overnight traveling distance.

2. The economic effect of transportation improvements is evidenced by increased industrial, commercial, residential development, and rural benefits.

3. Improvements in the highway system which will come about in the near future, in addition to the interstate highway system, will include another crossing of the Delaware River near the present bridge, a connection from the interstate system in Delaware to the Chesapeake Bay Bridge in Maryland, and further, construction of controlled access highways within the entire State of Delaware.

4. Long range highway improvements will call for construction, on a new location, of a north-south highway paralleling the present U.S. 13. Other probabilities in the distant future are improved east-west highways of the freeway type on new locations in the southern portions of the State.

5. In the Wilmington area the effect of the interstate system and the growth of suburban developments have already been felt, even though none of the interstate system is yet open to traffic.

6. The future impact of some of these highway proposals has been anticipated by the Regional Planning Commission of New Castle County in their master plan and proposed zoning arrangements.

7. The major improvements of providing additional parallel routes to our existing highways will have the effect of making the entire Delmarva Peninsula more accessible to surrounding areas.

SECTION XII - UNEMPLOYMENT COMPENSATION COMMISSION
WITH THE ESTABLISHMENT OF NEW INDUSTRIES IN THE STATE
WHAT WILL BE THE AVAILABILITY OF LABOR IN THE FUTURE?

1. The composition of the United States labor force has experienced a number of changes in recent years. The proportion of young workers has declined; the number and proportion of older workers have risen despite a tendency for earlier retirement, there has been a tremendous increase in number and proportion of women workers; and a

dramatic change has been the tremendous increase in part-time workers.

2. In the last few decades the proportion of farm labor to the total population has been declining at a fairly rapid rate. The importance of manufacturing has dropped. Service industries of all kinds have expanded rapidly along with the services provided by Federal, State, and local government, particularly in the areas of education, health, and welfare.

3. Labor trends indicate that automation, population increases, and social changes, will result in a shortened work week. It has been estimated that by the year 2060 the work week may well be less than 30 hours per week.

4. Based upon population estimates for the years 2010 and 2060, the labor force required for the year 2010 would be approximately 42 percent of the total population or 597,000 persons. By the year 2060, however, only 40 percent of the total population would be utilized in the labor force.

5. Young persons will not enter the labor force until a later age, as schooling required will be much more extensive than at present, and probably the age of retirement, even with an increase in the life span, will be at an earlier age.

SECTION XIII - DELAWARE CHAMBER OF COMMERCE

1. It has been estimated that for each 100 industrial pay-roll jobs created, employment is afforded six other wage earners in retail and service establishments.

2. New Castle County's growth can be mainly attributed to its geographic position and the excellent transportation facilities afforded by rail, water, highway, and air.

3. During the past 50 years the character of industry in Delaware has changed considerably and will no doubt continue this change for many years to come due to technological advancements.

4. Industry in Delaware now represents a well-diversified picture which is highly desirable for general economic stability.

5. During recent years we have seen the steady diminution of rail transportation since the introduction of the trucking industry. There are no indications that this trend will not continue as long as Delaware and the other states provide the highway system on which trucks operate.

6. The safe and economical development of nuclear energy will tend to equalize the cost of generating electricity throughout the world, and where this cost is a fundamental factor in determining industrial

locations, it will tend to eliminate the necessity of being close to sources of fossil fuels or hydroelectric plants, as determinative factors in selecting plant sites.

7. Certain tributaries of the Delaware River, such as the Brandywine, Christina, Red Clay, and White Clay, offer some flood hazard; however, insofar as the Delaware River itself is concerned in Delaware, the problem of flood control is minor.

SECTION XIV - CIVIL ENGINEERING DEPARTMENT - UNIVERSITY OF DELAWARE
SURFACE WATER SUPPLIES OF NORTHERN DELAWARE

1. Extensive development of the Brandywine, Christina, and White Clay streams through dam sites results in a combined safe yield for a 25-year recurrence interval with minimum development of 308 million gallons and for maximum development 480 mgd. Safe yields with a 25 percent allowance for unavailable storage would result in a combined Brandywine, Christina, and White Clay development of a minimum of 272 mgd, and a maximum of 402 mgd.

2. Accumulative rainfall for the years of record show a fairly consistent trend with an overall mean annual rainfall of 44.47 inches.

3. Accumulative run-off for the gaged streams also exhibited a consistent trend until about June 1953, when a noticeable drop in run-off rate was evident for all gaged streams. This reduced run-off rate continues up to the most recently available records, October 1956.

4. Most (85%) of the watershed area of the streams in northern Delaware lies outside of Delaware. Only the relatively small Shellpot Creek lies wholly within Delaware.

5. Based upon existing records the mean annual run-off of the five streams in northern Delaware are: Brandywine, 19.10 inches; White Clay, 17.05 inches; Red Clay, 18.05 inches; Christina, 17.14 inches; and Shellpot, 17.85 inches.

6. The means of the run-off precipitation ratio for the four streams are: Brandywine, 0.43; White Clay, 0.38; Red Clay, 0.41; Christina, 0.38. This ratio varies from year to year.

7. Although annual figures are important for determining long term trends, of primary importance for surface-water supply are the low-flow characteristics. The Brandywine, White Clay, and Red Clay exhibit similar low-flow characteristics. The Christina exhibits significantly lower discharges (mgd/sq mi), while the Shellpot has the lowest of the five streams.

SECTION XV - DELAWARE GEOLOGICAL SURVEY

1. In the Piedmont area, ground water is available only in relatively small quantities; well yields vary between one gallon per

minute and 150 gpm, with a mean yield of about 10 gpm. Such quantities are usually adequate for domestic and farm use, but not for irrigation or industrial use.

2. The flat topography of the Coastal Plain is not suitable for construction of large storage reservoirs of surface water. The sedimentary formations of the Coastal Plain form large ground water reservoirs. Optimum development of these reservoirs has not been accomplished, and ground water is abundant in many places.

3. The availability of ground water supplies may be the controlling physical factor in the development of the Coastal Plain.

4. The industrialization and concentration of population in the northern Coastal Plain would necessarily be accompanied by the construction of many housing developments and roads. Such construction will tend to reduce ground water recharge.

5. The availability of ground water is rather an elusive quantity because it depends upon many factors, most of which are difficult to determine in a quantitative manner.

6. Delaware lies in two geologic provinces; the Piedmont and the Atlantic Coastal Plain. The Piedmont is underlain by crystalline rocks. The coarse-grained sediments of the Coastal Plain (sands and gravels) form Delaware's principal aquifers.

7. Estimated ground water potential is calculated separately for northern Delaware and southern Delaware. This procedure has the advantage of providing estimates for areas which are experiencing industrial expansion and population growth at quite different rates.

8. The estimated portion of recharge available to wells, in addition to present pumpage, from the various aquifers in northern Delaware, totals 24 mgd.

9. The estimated portion of recharge available to wells, in addition to present pumpage from the various aquifers in southern Delaware, totals 419 mgd.

10. Recharge computations are based on the assumption that the co-efficient of infiltration is 50 percent of the precipitation, and this may not always be realistic. As the amount of recharge determines the ultimate safe yield of an aquifer, this important quantity is not well known in most areas.

11. In order to obtain the quantities of water potentially available, optimum well spacing will be necessary.

12. The ground water availability figures do not include water that is potentially available by artificial recharge, or means of reducing evapo-transpiration losses.

13. Even if recoverable recharges were known accurately, the question arises whether or not such quantities of ground water could be developed economically.

14. Any estimates of potential resources are valid only if salt water encroachment into aquifers can be prevented. It is assumed that the quality of water found in the aquifers discussed is suitable for most uses.

15. The estimated portion of recharge available to wells, in addition to present pumpage, is very small in the area north of the Chesapeake and Delaware Canal; at the same time the most rapid economic development and population growth will occur there. When ground water requirements will be twice as large as they are at present, full development may have been achieved unless conservation measures are taken.

16. Whereas the potential ground water north of the Canal is about twice the present usage, the situation south of the Canal is more favorable. Large quantities of ground water still await development, particularly in the Pleistocene and the Miocene series.

17. If a potential of about 400 million gallons a day is a reasonable estimate, the southern part of the State can look forward to more than a 20-fold increase in water requirements, subject, of course, to the proper development procedures and economic feasibility.

18. Although the 400 mgd of water should be physically available, its full development is unlikely since rural areas do not need so much water, and industry tends to gravitate to specific localities, and therefore, local over-development may occur in spite of large potential ground water resources.

19. The utilization of ground water will be limited chiefly by economic factors, particularly south of the Chesapeake and Delaware Canal; north of the Canal, optimum development may be more nearly achieved because the economic necessity will be more compelling.

20. Saline water in aquifers may occur in several ways: (1) as a result of the gradual invasion of salt or brackish water into the fresh-water-bearing sands; (2) as water trapped in a sediment during deposition (connate water); (3) as water which invaded a sediment during a high stand of sea-level sometime in the geologic past.

21. Connate water is present in some deep aquifers as indicated from a test hole drilled at the Dover Air Force Base.

22. Areas where salinity intrusion have been noticed include Lewes, Rehoboth, and Fenwick Island. Potential encroachment danger is present; however, along the whole Delaware Bay shore and the Chesapeake and Delaware Canal, and if great development occurs in the future, salinity intrusion is most likely to occur.

23. Salt water encroachment can be prevented by: (1) limiting pumpage along the shore; (2) creation of a fresh water barrier by artificial recharge from fresh water streams; (3) creation of fresh water lakes or ponds by the construction of small barrier dams across tidal streams.

24. Saline water conversion is practical in areas lacking natural fresh water supply. However, the economic feasibility in areas with fresh water available is a factor of prime consideration.

SECTION XVI - DELAWARE STATE BOARD OF HEALTH

1. There are 43 public water supplies throughout the State of Delaware including four small systems serving beach areas in Kent and Sussex Counties.

2. Thirty-eight of the public water supplies are secured from ground water. The four surface supplies, however, serve 56.6 percent of the population using public water systems, and one of these serves 49 percent.

3. The 250-gallon per capita demand of the users of surface water is more than double that (110 gallons) of the ground water supplies. This can be explained by the fact that the biggest surface supply, Wilmington, serves considerable industry, while most of the ground water systems are, for the most part, domestic water suppliers.

4. All the Kent and Sussex Counties public water systems are served from wells.

5. The major military installations in Delaware employ ground water as their sources.

6. It is estimated that approximately 50 percent of the population served by public water systems will be supplied from surface sources in the year 2010. Assuming that 700,000 persons are thus supplied, the surface water demand would be about 135 mgd. This means that ground sources will be called upon to supply approximately 195 mgd for domestic water needs in the year 2010 in Delaware.

7. Our ground waters show a progressively increasing pattern of low, corrosive pH, and high iron content in a southerly direction. These conditions dictate an increased cost for ground water over and above similar supplies requiring no removal of iron or adjustment of pH.

SECTION XVII - STATE SOIL CONSERVATION COMMISSION

1. The number of farms and the number of acres of farm land being cropped have slowly but steadily decreased. At the same time, the average Delaware farm has become appreciably larger.

2. The acreage of truck crops has also been increasing in spite of the overall decline in the use of cropland.

3. In the face of decreasing acres of cropland being harvested, gross income from crops increased spectacularly.

4. Individual and group drainage-ways constructed and approved have contributed to the increase in farm income. As the pressure of increasing population develops in the years to come, it must be expected that water management will become even more significant.

5. Delaware has a very high percentage of land that is capable of being cropped forever.

6. Very little or no studies have been made in Delaware to fix the sources of sediment loads in the various waterways of the State. The sediment studies on the Brandywine Creek reflect total sediment loads and cannot be used as a source of material for tracing the sediment load due to erosion. However, since most of the material originates outside of Delaware, tributable to the Brandywine, the information is not completely applicable for use within the State.

7. There is apparently no research data to show the effects of soil conservation techniques on low and high stream flow in Delaware.

8. The possibility is indicated from studies on the Brandywine Creek that sediment damages may be considerably reduced by virtue of the upstream application of soil conservation practices and techniques.

9. Generally, soil conservation techniques have been found to diminish and slow up runoff.

10. Soil conservation techniques adapted for upstream, soil and water retaining purposes have proved beneficial; however, soil conservation techniques of drainage can have the opposite effect, particularly in the early stages of development.

11. Impoundment of water is encouraged during the dry season in ditches and drains that are used to remove excess water during flood periods.

12. Within Delaware, excluding the marsh lands, there are approximately 327,000 acres of imperfectly and poorly drained soils. Of these, approximately 21,000 acres are in New Castle County; 100,000 acres in Kent County; and 206,000 acres in Sussex County.

13. Moderate erosion has occurred on much of the agricultural lands of Delaware. There are 3 distinct types of flooding which occur in Delaware. The Brandywine represents one type of flooding in which during high intensity storms the lands immediately adjacent thereto become flooded. The second type of flooding occurs in relatively flat

portions of the Coastal Plain area of the State, where drainage and related flood control measures have not been put into operation. The third type of flooding is some combination of the first two. Land loss to agriculture, due to inundation, cannot be satisfactorily separated from losses due to lack of drainage.

14. In 1955 the irrigated acreage rose to an all-time high, 9,068 acres. Another sharp rise occurred during 1957, when an all-time high 14,269 acres were irrigated.

15. Approximately 4 inches of water was the average application for the entire 14,269 acres irrigated in 1957. This constitutes almost 1,554,000,000 gallons of water used for irrigation by farmers during 1957.

16. On the basis of a 60-day growing season, and a 12-hour day, the average pumping rate during application amounted to something over 72,000 gallons per minute for the entire State.

17. In 4 years the total annual amount of water being used for irrigation has multiplied nearly 8 times.

18. Of the 79 percent of the total irrigation water used on farms, distribution of water sources was 26.8 percent for dug ponds, other ponds 6.7 percent, streams and lakes 48 percent, and wells 18.5 percent.

19. Irrigation water use was shown to be taking 55 percent from surface sources and 45 percent from ground water.

20. The present trend of the agricultural changes were continued, whereby the number of farms will decrease in the future although the average size of farms will continue to increase.

21. In New Castle County almost all of the land now in farms can be expected to be used for homes, schools, industries, roads, parks, etc. Large areas in Kent and Sussex County farmland also will be converted to other uses. These changes will indicate a probable decrease in agricultural population.

22. Agricultural land values will continue to rise, and as this land becomes more valuable substantial areas now in trees may be cleared for crop production.

23. The shifting of land use may result in no net change in the amount of land for crops, in spite of all the land use for new homes, schools, industries, roads, etc.

24. Increased land values will create economic pressure that will force an intensification of farming practices which will be directly related with increased irrigation water needs.

25. If the present trend of loss of farmland continues, it is

estimated that by the year 2060 there would be less than 1,000 acres of land available in New Castle County for cropland.

26. Present-day agricultural commodity surpluses and the resulting Federal programs to reduce crop production, have had the effect of causing significant reductions in cropland use during the past years. Rising labor costs and increasing machinery costs are also factors which must be taken into consideration.

27. In conjunction with the rapidly expanding population, both nationally and in the Delaware River Basin area in the future, the problem of sufficient food can conceivably become a critical factor and increased farm production is clearly indicated.

28. Certain land within Delaware should not be cropped but should be left to be developed as forest land or wildlife areas in accordance with agricultural practices and needs.

29. The maximum amount of land suitable for cultivation in Kent County roughly totals 200,000 acres. In Sussex County, the maximum of land suitable for permanent cropland is close to 420,000 acres. This cannot be realized unless thousands of acres of existing woodlands are cleared for cultivation. If our need for food becomes as great as some present authorities predict, it must be conceded that cropland will have very high priority. This unprecedented shift to cropland will hardly occur except under conditions of extreme need.

30. Supplemental water, namely irrigation, is an absolute requirement for maximum economic returns from certain crops. Other crops are substantially improved through the use of irrigation.

31. Evidence shows that in time nearly every farm will have irrigation equipment, and other crops will also be irrigated because the initial cost and depreciation of that equipment will have been charged against the crops for which the irrigation equipment was purchased.

32. The average application of water at the present time is 7-8 inches per season. If this application is applied over 60 irrigating days, 1,735 mgd is the amount of water which may be needed under maximum development conditions.

SECTION XVIII - WATER POLLUTION COMMISSION

1. Nature has provided us with a tremendous asset of self-purification of waste material. To ignore this natural phenomenon would be wasteful.

2. Procedures are reasonably well established whereby domestic waste can be handled or treated satisfactorily without excessive cost to the taxpayer. However, there are many industrial wastes to which municipal systems are not available or which are not amenable to domes-

tic or municipal type treatment.

3. The effect of industrial wastes discharges upon water supply and water use varies throughout the country and is dependent upon the distribution and type of industries.

4. As the river valleys grow with respect to population density and industrial development, each gallon of water available will experience additional reuse. The effluent quality will become of greater significance.

5. In a river valley, such as the Delaware with its rapid development and numerous industries, the cost of additional treatment due to the unavailability of that "additional gallon of water" can conceivably cost the users many millions of dollars.

6. The waters in the Delaware Valley receive every conceivable type of waste discharge, even minute quantities of radioactive wastes; however, this latter type of discharge may become a problem in the not-too-distant future.

7. The State of Delaware has its share of industrial waste problems. We have various chemical industries, oil refineries, steel, paper, textiles, tanning, nylon, meat packing, poultry, food processing, etc.

8. The problem of industrial wastes and their treatment is affected by the volume of dilution-water available and the permissible use of streams.

9. Waste treatment should be based on or be consistent with the water usages downstream. In the estuarine portion of the Delaware River Basin, these needs are further complicated since both up- and downstream users within the zone of influence can be affected materially due to tidal movements.

10. Water uses may include municipal water supply, industrial process water, cooling water, water for navigation, recreation, fish and wildlife, shellfish, farming, and as a recipient for treated waste.

11. The treatment of various industrial wastes, tributary to our streams, must be evaluated separately and specifically. Location and type of industry have a material effect upon treatment needs and the approach to the problem.

12. Pollution affects each and every water use, consequently, its influence is fundamental to the future of each interest.

13. In existing areas of moderate to heavy population and industry density, it is only reasonable or equitable to conclude that the

self-purification action of a stream must be considered as an integral part of pollution abatement.

14. We must not be placed in a position whereby we are saturated with population and industry without the recreational facilities needed for full enjoyment of life itself.

15. Of the total 51 communities requiring waste treatment, 40 have treatment provisions and 8 of the 11 remaining communities are actively engaged in providing waste treatment.

16. All institutions in the State of Delaware have waste treatment except one which is now under construction.

17. Delaware has a great number of industries, both small and large, for its size. Of the total 677 industries, 380 or 56 percent are considered wet industries having a liquid process waste. Of these wet industries, 280 enter municipal systems. Treatment is provided for 332 wet industries or 87.5 percent. Of the remaining, 12.5 percent, which constitutes a total of 48 industries, 30 now enter municipal systems and are not considered as having treatment since the municipalities lack treatment facilities. However, these 30 industries are in municipal systems actively planning construction.

18. Estimated reduction of pollution, both domestic and industrial, approximates 73 percent. Except for some local problems the ability of self-purification of the waters within the jurisdiction of the State of Delaware is not being exceeded by this loading.

19. An excess of 50 percent of the small industries in Delaware are located in New Castle County.

20. Fifty of the 170 industries in Kent and Sussex Counties are significant water users.

21. The metals, petroleum, petroleum products, paper, and allied industries which receive water from municipal installations are in New Castle County.

22. The poultry, meat, and fish type industries are in greater number in the lower two counties.

23. Cannery and dairy type industries are equally distributed between New Castle and the two lower counties.

24. Chemical and Allied industries are predominantly in New Castle County; however, Kent and Sussex counties have 20 such industries as compared to 72 in New Castle County. A complete inventory including domestic, industrial, and irrigation use has been made for the State of Delaware. These inventories have been segregated into industrial water, municipal water, ground water, surface water, and a summary water use.

25. The average total for all water uses in the State of Delaware is approximately 867 mgd. The more significant 30-day maximum is 1162 mgd. The greatest use is from surface sources. Of the 30-day maximum, use, 75.6 percent is for industrial cooling and steam generation.

26. In New Castle County there is essentially no water that can be considered as out-of-basin withdrawal. Similarly, Kent County withdraws essentially no water out of the Delaware River Basin. In Sussex County, the percentage of out of basin water is considerably reduced to approximately 25 percent of the total use in the County.

27. The total industrial water use within the Delaware River Basin totals 827 mgd and excluding steam generation in the Delaware River results in a total 104 mgd withdrawn. Further, of the total industrial use, 87.4 percent is cooling water.

28. The cooling and steam generation water withdrawn in the State of Delaware in 1958, totaled 887 mgd. Of this total, 153 mgd was fresh water and 733 mgd brackish. Of the total in-basin cooling use, 90.7 percent was brackish. The total surface water withdrawn from brackish areas constitutes 88 percent of the surface water used for cooling purposes.

29. The potential benefits of atomic energy should be fully recognized. The goal should be the attainment of radiation protection with minimum restriction on the early development and utilization of these benefits.

30. State governments are facing a grave challenge in the near future in providing adequate control to prevent harmful radiation exposure in the environment. Personnel, equipment, and a period of time in which to develop confidence are basic to any successful program.

31. Many new factors must be considered in relation to utilizing water sourses for radioactive waste disposal. Tremendous volumes would be required for dilution of the radioactive wastes. The food chain is a predominant factor. Thermal and density stream flow patterns near discharge must be studied and known thoroughly. Time is the only factor affecting any reduction in the radioactivity of material remaining in suspension. Radioactive sediments may cause buildups at low flow and resuspension during flood flows.

32. The evaluation of the radioactive water pollution problems requires knowledge of a natural background radiation, the characteristics of the radioactivity present, and information on the kinds of radioisotopes from the sources of contamination.

33. From a public health standpoint, it is necessary to consider exposure to increasing radioactivity due to both national and man-made sources.

34. There are many types and qualities of radioactive material

which are a potential waste.

35. In general, two principles are employed in radioactive wastes disposal: dilution and release, or concentration and storage. Treatment of these wastes differs from the treatment of other waste materials.

36. River mud samples may reflect many weeks of accumulation of soluble suspended radioactivity, depending upon the hydraulic characteristics and flow of the stream.

37. Experimental research is still in full force to determine the takeup of radioactive material by living organisms and the physiological effect upon humans.

38. Suggested disposal methods for highly radioactive wastes include disposal into deep wells, salt domes, or salt strata, hydrologic basins or troughs, and coastal formations on the salt water side of the interface between the salt water and the fresh water, as well as ocean disposal. However, the latter would require a very carefully studied evaluation.

39. The problems of control and treatment of radioactive wastes are many and complex. Solutions to these problems can be found if efforts are made by appropriate agencies.

SECTION XIX - WATER QUALITY IN THE LOWER DELAWARE RIVER WITH SPECIAL EMPHASIS UPON POLLUTIONAL ASPECTS

1. When dealing with an estuary one cannot emphasize too strongly that such a body of water has certain inherent complexities which are not present in streams unaffected by tidal action.

2. Due to the nature of water movement in the estuary, certain conditions are created in regard to pollution buildup and recovery which need special considerations.

3. An estuary receiving pollution in the form of a continuous discharge will result in a concentration buildup far exceeding that which can be anticipated from the uniform dispersion of the total daily loadings.

4. An estuary such as the Delaware River is, in essence, in a state of equilibrium and presently the daily loading is only a small portion of the existing accumulated concentration within the stream at any time.

5. Some of the more important factors of flow, transit time, temperature and dispersion, have variable effects in different portions in the estuary. The effect of increased flow upon water quality is not the same in the upper reach of the estuary as compared to the lower reach.

6. The pattern of runoff and total volume involved are extremely important with regard to pollution buildup and recovery.

7. Sediment problems will always be present, either through direct solids discharge, erosion, or chemical coagulation, and/or flocculation of industrial-type wastes. Regimentation of natural runoff pattern will reduce the effect of scour.

8. The total volume of water within the drainage basin area is extremely important, in that each gallon of water carries dissolved oxygen and has a definite recovery ability Any decrease in volume will lessen the total recovery capability. Benefits derived from controlled flow and/or diversion must be carefully weighed against the disadvantages in specific areas with regard to pollution abatement.

9. Transit time, which represents the average movement time of contaminants, is of comparatively long duration, pollution-wise, which, in turn, makes the Delaware River a large waste recovery system. The recovery capacity of this drainage basin system will dictate the limit of present and future loadings, since wastes are not carried to the sea but are stabilized by nature before reaching the bay itself.

10. Due to the long transit time inherent in the Delaware River Estuary, controlled and/or augmented flow in the upper basin will result in a change of pollution regimen and of salinity movement. Any short-term estimate to determine the maximum concentration buildup of either pollution or salinity can result in extremely low values.

11. The range of salinity within the estuary is of importance to shellfish, fish and wildlife, industrial, and ground-water interests.

12. Water quality does not materially change between high-and low-water slack, and the only noteworthy change that takes place is a shift up or downstream. This fact emphasizes the importance of clearly defining the effect of pollution or the buildup pollution as related to flow with respect to location and tidal conditions.

13. During increased flow periods in the Delaware River, the water quality sag shifts from upstream areas downstream into the State of Delaware.

14. This shift takes place with increasing flow stages, and decreasing water quality will progressively reach the State of Delaware until approximately 5,000 cfs is reached. At this low flow stage, a reversal takes place with continued increased flow and progressively improved water quality results.

15. Measurements made on the prototype at a maximum flow of 7,100 cfs, still did not produce quality in the State of Delaware equivalent to that found during the lowest flow period, even though it was rapidly approaching the stage of quality experienced during the

lowest flow periods.

16. Since Delaware will experience decreased water quality with increasing flow, induced by upstream impoundments, either increased waste treatment measures must be provided upstream from the State of Delaware, or augmented flows exceeding 8,000 cfs must be the minimum control.

17. In order for the river quality not to drop below the present conditions evident within the State of Delaware during periods of dry weather flow, it would be necessary for the State of Delaware waste dischargers to provide further treatment in addition to increased waste treatment measures upstream.

18. Under the presently suggested flow control of 3400 and 5500 cfs, the State of Delaware would, of necessity, have to provide secondary treatment for a present primary treatment discharge load of one hundred thousand pounds (B.O.D.).

19. One must recognize such potential benefits of flood control water supply, and recreation upstream provided through regulated flow practices. However, improper regulations could create a non-beneficial effect on the lower reach of the estuary, specifically through decreased water quality while still being beneficial upstream.

20. If complete treatment of all wastes is accomplished, it is estimated that by the year 1980 we shall be confronted with the artificial and natural recovery capacity limit for waste tributary to the Delaware River. The gravity of the waste removal phase is ever present in the not-too-distant future. The solution of the overall waste problem must, of necessity, take a new approach.

SECTION XX - BOARD OF GAME AND FISH COMMISSIONERS

1. In an effort to predict that quantity of water necessary to meet recreational needs in the State of Delaware during the next 50 to 100 years, considerable use must be made of projected population figures. However, paralleling this will be the shorter working day and working week trend. These two aspects will compliment each other. Recreational needs may not change in proportion to population but may multiply many times as the population doubles.

2. A constant challenge exists to provide increased recreation for the increased number of people by wise and careful management plans.

3. Various fish and game management techniques have evolved which will permit more sports on smaller land and water areas. However, this in itself will not fully counteract the increasing competition for lands and waters by other interests.

4. It will be necessary to strive for the preservation of many more public hunting and fishing areas, the more efficient utilization and increased multiple use of existing ones during the next 100 years.

5. In order to preserve the many benefits which fish and wildlife resources make available to the people in the State of Delaware at the present time, certain minimum water quantities at a quality suitable for the reproduction and growth of fish and wildlife should be obtained.

6. The waters of the inland lakes and ponds must be kept at least at its present level and preferably at a higher level in the future.

7. Preliminary observations of the quantity of siltation in various lakes in Kent and Sussex Counties indicated that silt has been deposited at the rate of approximately one-quarter inch per year over most of the lake bottoms. Within the next 100 years costly dredging will have to be undertaken to remove the silt.

8. The minimum quantity and/or oxygen requirements needed for fish survival are still not fully understood. The formerly accepted 5 ppm oxygen tolerance level, so long used as a reference, may be too high especially in reference to the warm water species such as largemouth bass and bluegills.

9. The increased stocking of fish over a longer period of time and over more miles of streams, could conceivably take care of six times as many fishermen as they do now.

10. The present demand from fishing, boating, and other water activities is at an all-time high.

11. Many people are benefiting from the recreational assets, and indirectly from the revenue derived in pursuit of and in the actual recreation. The demand for residential sites on the shores of stable water areas is tremendous and increasing at a rapid rate.

12. Irrigation during several dry summers in the past has seriously depleted the water quantity in several of Delaware's fresh water ponds.

13. A restoration, maintenance and acquisition of 45 to 50 ponds is a major part of the future development program of the Game and Fish Commission.

14. The coastal marshes of Delaware, comprising approximately one-eighth of the States area, are among the most productive in the country. The value of these marshes to fish, wildlife, and ultimately to recreation,is great. The role they play as nursery areas for commercial fish and shellfish have a decided impact on populations throughout the entire Delaware Estuary. It is established that these areas are the prime producers of nuturients, especially phosphorus.

15. The marshes throughout the country have been disappearing at an alarming rate. Delaware has been no exception. Increased demands for industrial and residential sites, dredging of shipping channels, fill-

ing marshes, and increasing water uses, have resulted in an up-surge in dollar real estate value of those remaining.

16. In the next 50 to 100 years, it is conceivable that marshes will be classified for waterfowl hunting in the highest category possible as a result of public demand for hunting areas.

17. Studies indicate that the mosquito problem can be effectively and permanently solved by moderate changes in water level and by the impoundment of water.

18. Efforts should be directed toward biological control of pest mosquitoes. Any area should be studied for the best method of control, realizing the values of fish and shellfish, resting and nesting areas for waterfowl and habitat for furbearers will have to be protected if needs for recreation are to be approached.

19. Studies indicate that a combination of diking and chemical control have definite possibilities of providing economical and permanent methods for control of mosquitoes.

20. With adequate planning, marshes and inland ponds often can be improved in conjunction with bridge construction and the installation of dams and tidegates with considerable benefits to hunting and fishing interests.

21. Areas for disposal of dredgings should be studied so that the most valuable fishing and spawning areas are not destroyed, and where possible,the spoil should be moved to less productive areas. Other offshore areas will need to be determined by marine studies. In some areas it is feasible that these materials should be used in building dikes and levees which would be of benefit to wildlife.

22. Planning and zoning should insure preservation of the only remaining natural areas that are available for recreation and commercial fishing. It is highly desirable to obtain and maintain such facilities near the most densely populated section of the State.

23. Both sport and commercial fisheries will be influenced by changes in salinity and changes in the manufacture and transport of nutrients.

SECTION XXI - UNIVERSITY OF DELAWARE MARINE LABORATORIES
BIOLOGICAL EVALUATION OF THE DELAWARE RIVER ESTUARY

1. Man-caused changes in river flow, although influential in the distribution of estuarine organisms are not as damaging as pollutants. Both changes, river flow and pollutants, are engineering problems that must be better solved than they are today if biological productivity of the estuary is to remain high or to be improved.

2. We should be ever critical of man-made changes of naturally

occurring factors affecting the estuary, particularly of the river flow characteristics, until it can be demonstrated that these will not be detrimental to estuarine life, especially to commercially valuable species.

3. The ability of aquatic organisms to conserve water in their tissues under varying salinity and associated environmental conditions is what determines where those organisms can exist within the estuary. Variations in the fresh water flow that brings about changes in the pattern of water circulation of the upper estuary can markedly affect the distribution of planktonic species and those bottom-dwelling species, such as the oyster, that spend their larval stages carried by the currents.

4. In addition to the "old fashion type" of soil, sewage, and industrial pollutants, a new more deadly series--detergents, insecticides, and radioactive substances--poses an even more critical problem than does fluctuation in the fresh water flow.

5. The fresh water flow from the Delaware River Basin and all its contained minerals, nutrients, and pollutants, have an effect upon some 4,000 sq mi of coastal waters bordering the States of New Jersey, Delaware, and Maryland.

6. The value of marine fisheries resources harvested yearly from this area added to the investment in vessels, equipment, and factories processing the harvest, is in excess of 60 million dollars.

7. This coastal water area is responsible for a large fisheries harvest, for minerals and for recreational uses valued at several millions of dollars, with an ultimate value to the consumer probably measurable only by hundreds of millions of dollars.

8. Tidal marshes have been found to be highly productive of estuarine life, particularly plants, and these plants contribute much food, organic detritus, and nutrients to estuaries.

9. If all tidal marshes were lost from the productivity of the estuary, our fisheries harvest might well drop to less than half of their present volume. A positive program of marsh utilization must be adopted so that industry, agriculture, and recreation (through elimination of mosquitoes) can co-exist with fisheries.

10. Impoundment and flooding of marshes for the dual purpose of mosquito control and water fowl and/or fur bearer management, are contrary to the best interests of marine fisheries. A suitable number of tidal marshes must be managed for maximum benefit to these fisheries.

11. The Little Creek area is, if a marsh must be lost from estuarine production, a good choice for a dredge spoil disposal area, on the basis of present knowledge.

12. Wanton destruction of renewable natural resources, instead of seeking opportunities of increasing this production afforded by our accumulating scientific and engineering abilities, is not only a crime today, but it is vital to future generations that mankind better utilize our rapidly diminishing per capita natural resources. The problem is to provide for our future generations by developing the ability to engineer changes that will have to have a beneficial effect upon the biological productivity of the Delaware River Estuary.

SECTION XXII - STATE HIGHWAY DEPARTMENT BEACH AREAS AS FUTURE POPULATION GENERATORS

1. Today 90 percent of the beach population prefer the Atlantic coast line of Delaware with the remaining 10 percent preferring the Delaware Bay coast line. From the existing desirability of the Delaware Bay beaches, it is estimated that in the future 6 percent of the total beach population will be concentrated in the area of Lewes Beach to Broadkill Beach, with the remaining 4 percent being scattered northward toward Kitts Hummock.

2. Along the Atlantic Ocean, it is estimated that the State Beach front can provide for 228,000 persons each day, while the State park lands, which lie behind the beach front, can adequately support an additional 116,000 persons each day. The Federal-owned land should adequately support an additional 91,000 persons if developed into a State park. Private interest controlled-areas are capable of supporting an additional 109,000 persons each day. The sum of these ownerships, both public and private, can support approximately 544,000 beach users each day.

3. It is estimated that in the year 2010 a total of 3,914,000 persons will visit the beaches in the State of Delaware. It is further estimated that the area to be covered by homes and businesses will expand from the present, approximately 1,000 acres along the Atlantic Coast to 3,750 acres in the year 2010.

4. In the year 2060, it is estimated that 9,025,000 persons will visit Delaware in a season, of which 423,000 will visit those beaches in a single day. The permanent population of the beach area will be 30,700, and the summer population will be 207,000 and cover approximately 8,600 acres.

5. If beaches and adjacent areas are properly planned, for the year 2060, lands belonging to the State and Federal Government will be capable of supporting most of the daily beach users.

SECTION XXIII - STATUS OF SALT WATER BARRIER EVALUATION

1. The request for an evaluation of a salt water barrier was initiated by the State of Delaware to inquire into its practicability as a possible means of meeting the projected water needs in the lower

Delaware with its associated benefits, and thereby becoming part of an overall water development plan for the Delaware River Basin.

2. A barrier, if feasible, would help recharge underground aquifers in upper Delaware and southern New Jersey, in addition to providing a surface supply.

3. A staggering pollution complexity in the not-too-distant future will, of necessity, need consideration and this complexity faces the people of the Delaware Valley whether an adequate pipe line, aqueduct or barrier were constructed.

4. With respect to pollution control, it is quite clear that the economical and technological problems instigated by a barrier will be little different from the problems which exist should no barrier be constructed.

5. It should not be construed that a barrier would or could be a substitute for upstream impoundments. The fact remains that a barrier dam is not a storage reservoir, it is entirely dependent upon upstream impoundments for maintaining its capacity during low flow periods. In essence, a downstream barrier would provide a means of making fuller use of already stored waters.

6. The day will soon come when human activities within the Delaware River basin water supply area will no longer be able to afford the luxury of wasting fresh water. Multiple use of fresh water throughout the basin will be required to maintain and improve the economy and habitability of the area.

7. The barrier has the potential of being the source of the greatest amount of fresh water, at the least cost for the most people, especially in the heavily urbanized areas below the fall-line.

8. The creation of a fixed shoreline will greatly improve recreation facilities and will encourage the development of new waterfront industrial sites on both sides of the river.

9. Increased depth of the river and the one directional flow of the current, both of which would result from the barrier, will afford important advantages to water transportation and to industrial water users, especially those requiring large amounts of water for boiler and cooling purposes.

10. The barrier will create several problems, particularly with regard to pollution control, fish and wildlife, and water transportation. However, it is highly probable that these important water use problems can, through careful planning, be solved to their own betterment when coupled with a permanency of a barrier.

SECTION XXIV - REVIEW OF FACTORS AFFECTING SALINE WATER CONVERSION

1. When fresh water achieves the status or value of food itself,

the price to be paid to obtain such a commodity is of secondary importance. Under such circumstances, where possible, the conversion of salt or brackish water to fresh water is a matter of technical ability and not an economic consideration. Further, the price of water over the world may vary from essentially no cost to a commodity considered as expensive as determined by supply and demand. In areas where water is plentiful there is little consideration of cost involved. However, in arid regions and on many small islands surrounded by the sea, the need for a fresh water supply over-shadows the cost.

2. Various techniques for producing fresh water from salt water have been known for many years. Primary efforts in the last decade have been directed toward desalting water at a reduced cost so that it may be competitive in cost with sources of fresh water under specific conditions.

3. At present it is estimated that large scale conversion units may produce fresh water at 50 cents per 1,000 gallons in the near future. Whether this cost applies at the source of supply or at the point of consumption is not made clear. This cost, compared to the 1955 cost of excess water in Philadelphia at 9 1/3 cents per 1,000 gallons ($93 per million gallons) delivered to the consumer, is excessively high.

4. There is little doubt that salt water conversion will play an increasingly important role as a source of fresh water in the future. The immediate major decision to be made is an estimate or evaluation of how significant salt water conversion may become to the State of Delaware. Consideration is largely dependent upon the comparison of the need and the cost of the water, namely, whether salt water conversion will become economical and/or competitive with other fresh water sources available to other water users in the basin.

5. Unfortunately, all potential users of converted saline water would not be adjacent to ocean sites. The disposal of the brine residue from salt water conversion in inland areas or upper areas presents a serious problem. The cost of power for such salt water conversion is a critical issue as it may be quite variable from location to location.

6. If conversion is to be used without too much difficulty in the lower Delaware River, it would have to be located in areas adjacent to waters highly saline.

7. Unless an economical supply of water for industry and agriculture can be supplied, salt water for general use cannot be a reality but merely an emergency source which will remain as a small scale operation.

8. If waters have to be transported to a great distance, it is conceivable that salt water conversion could become competitive costs for treatment for fresh water. The State of Delaware becomes doubly vulnerable if reservoirs for holding water are constructed considerable distances upstream instead of downstream, as behind the barrier.

9. A structure such as the proposed barrier dam could become extremely important to the State of Delaware in order to maintain fresh water resources downstream and thereby provide water economically to the people of the State of Delaware.

SECTION XXV - STATE PARK COMMISSION

1. Nearly all forms of recreation hinge directly upon available adequate water for each specific activity.

2. Swimming is still the primary attraction of a park. Next to swimming, probably the second greatest public demand is for picnic facilities. Picnickers also want to be near water especially during hot dry summer months.

3. Each State park should provide at a minimum 10 acres of land for every 1,000 residents within the area it serves, plus additional acreage in outstanding natural resources recreation such as beachfronts, which attract a higher percentage of non-resident visitors.

4. A minimum of 10 percent in such areas should consist of surface water for complete recreational purposes. Only Trap Pond meets this minimum of the three sites presently under control of the State Park Commission.

5. In accordance with the 10-acre standard for State parks, Delaware should have in the year 2010, 14,268 acres or 22.3 square miles of State park land. In the year 2060, this figure will reach 33,528 acres or 52.5 square miles of State park land.

6. Using the 10 percent surface water area minimum for recreational use in the year 2010, 1,426 acres or 2.25 square miles of water area are needed for recreation. Similarly, by 2060, 3,552 acres or 5.25 square miles of water area will be needed for recreation.

7. Delaware State Parks when fully developed could draw an average yearly attendance ranging from a number equal to the State population to three times that figure, plus an additional allowance for out-of-state visitors.

8. Anticipated use by an increasing population will necessitate purely recreational use of all inland waters now available on lands where worthy of State park development in Delaware.

9. Waters of the Delaware River and Bay, although an outstanding resource to shellfisheries, commercial and sports fisheries, are limited in supplying potential for other forms of recreation. Insects and the murky conditions of water are not conducive to good bathing.

SECTION XXVI - PROJECTED WATER NEEDS FOR THE STATE OF DELAWARE

1. The projected total domestic water use in 50 years indicates

the need ˋ.81 times the present domestic use or a total of 178 mgd.

2. If we were to assume the entire minimum development of surface waters of 270 mgd could be assured for the State of Delaware, we would have less than half the water required for New Castle County alone in the year 2010 and considerably less for the year 2060.

3. Our projected needs for the year 2010, excluding industrial and cooling and steam generation requirements, total approximately 1300 mgd.

4. If all surface (not including the Delaware River) and ground waters, tributary to Delaware, were readily available, less than half of our requirements for the year 2010 could be satisfied. The only fresh water sources readily available to the State of Delaware to meet this oncoming demand is the Delaware River.

5. The three often discussed potential dam sites in northern Delaware are located within the White Clay, Christina, and Brandywine watersheds. Only the Christina site lies wholly in the State of Delaware, emphasizing the lack of reservoir sites in this State.

6. New Castle County's projected needs for fresh water in 2010, excluding industrial cooling and steam generation, is 567 mgd. Since the 272 mgd potential is faced with the certainty of being considerably less, Delaware's confronted with a water need in 2010 exceeding 300 mgd in New Castle County alone, and it would not appear too extreme if this value reached or exceeded 350 mgd.

SECTION XXVII - STATE FORESTRY DEPARTMENT

1. Woodlands, irrespective of their location, or of the relative commercial wood production potential may contribute immeasurably to soil erosion prevention and water absorption.

2. Farmers own more than half of the forest land. Wood lots are still an important integral part of the average farm.

3. Nearly 400,000 forested acres are found within this State. Of Delaware's three counties, Sussex contains two-thirds of the State's timber volume.

4. Sussex County with its sandy soils and level terrain, is covered by approximately 42 percent of forest cover, mostly in southern yellow pines. In the more densely populated northern counties of New Castle and Kent, forests cover only 21 percent of the land.

5. Of the total commercial forest-land in Delaware of 391,000 acres, 9,000 acres are under public control, which includes 8,100 of State owned forest-land and 900 acres of Federal owned forest-land. The remaining commercial forest-land area is privately owned, of which 215,000 acres are on farms and 167,000 acres are owned by industrial and other interests.

6. In a matter of runoff rate in Delaware, research is not likely to find a perceptible difference between the intensely managed and the unmanaged forest area.

7. Forest management and reforestation is only a minor role to offer in any drainage problem program.

8. The effect of present management of drainage on forest may both be detrimental and beneficial depending upon the objectives of the individuals concerned.

9. A root mass and duff on a forest floor forms a continuous spongy layer that protects the porocity of the underlying soil; that the water absorbing capacity of this layer is valuable and that when it becomes completely saturated the surplus can trigger floods. Consequently, the greater acreage of this spongy aquifer that is maintained in the basin, the less likelihood that there is of devastating flood and drought occurrence.

10. None of the Delaware State Forests are large enough or so situated as to materially influence surface water supplies used by municipalities or industries within the State.

11. Forests, presently constituted and managed, do contribute to underground water reserves and naturally to runoff retardation and transpiration to no greater or less degree then unmanaged forest areas.

12. The Edgar M. Hoopes Reservoir of the Wilmington Water Department, however, is an example of foresight and planning to meet municipal water needs. This reservoir has been protected from excessive siltation and minimum evapotranspiration losses secured through the medium of reforestation of its adjacent slopes with conifers.

13. The situation in Delaware is similar to the national picture in that three-fourths of the productive timber lands of this area are a part of farms and in consequence the key to our future timber supply is in the hands of those who own these small forests.

14. It takes 25 to 100 years to mature a forest-crop and since 99 percent of all Delaware forest lands are privately owned, in small individual holdings, its owners cannot afford to own, pay taxes on them, and manage such a long-term crop in the face of every increasing land-use pressures accompanied by rising land values. It is, therefore, concluded that economics will determine how much land stays in forest cover.

15. Forest cover can and does influence climate, and by such influence contributes to increased precipitation, inhibits flash runoff, improves infiltration rates of most soils, impedes both wind and water erosion rates, regulates stream flow, and generally contributes a multitude of benefits for civilization.

16. Some characteristics desirable from the standpoint of reducing flood flows may not be compatible with maximum water yield objectives. Maximum flood control calls for the retention and dissipation of water in the watershed, whereas maximum water yield requires the reduction of evapotranspiration losses.

17. Forest are replenishable, both by natural and artificial means, provided other essential elements of plant life are adequately available.

18. In areas where land-use is subject to uncontrollable factors of change, forest survey data is likely to become obsolete and unreliable quickly.

SECTION XXVIII - LEGAL ASPECTS

1. From an evaluation of the legal aspects, it appears quite evident that the State of Delaware is in urgent need of legislation to permit effective participation with other governmental entities and to construct facilities with regard to its future water needs.

SECTION IV

RECOMMENDATIONS

It is recommended that:

1. This report be considered a part of a living document, in that all matters discussed should be reviewed periodically and modified as the occasion demands.

2. Due to the impending water shortage, legislation be passed for the control and use of the surface and ground waters within the State and to facilitate interstate representation and cooperation with regard to water resources planning and development.

3. Since the Corps of Engineers is preparing a plan for water development on a regional basis recognizing primarily the terrain and the forces of nature, it becomes imperative that certain sites suitable for the construction of dams be selected in the piedmont area of Delaware. Such sites, paradoxically, are in the region of the most intense population density and development of the State. Therefore, immediate action should be taken to prepare legislation derived specifically for the acquisition and purchase of dam sites within the State as the initial phase of preparing for the future.

4. Appropriate legislation be provided as soon as possible to establish a coordinated organization to fully represent the various related interests within the State of Delaware. This organization would:

   a. resolve problems related to multiple use of land and water resources through statewide planning and zoning to insure proper development of the land for the common good and yet protect the rights of the individual;

   b. act as a clearing house for research needed with regard to the various fields of interest and thereby perpetuate the flow of needed information and avoid duplication of effort;

   c. include appropriate technical representation directly and indirectly associated with water use.

SECTION V

TOPOGRAPHY OF DELAWARE

5.01 GENERAL

Delaware has a total area of 2,399 square miles. The State is 96 miles in length from north to south and varies from 9 to 35 miles in width. The largest portion of the State is classified as Coastal Plain, the remaining small segment in the northwest section being within the Piedmont Plateau. The southern edge of the Piedmont Plateau in Delaware is defined approximately by a line running parallel to U.S. Route 40, and continuing to where Route 40 crosses the Delaware River at the Delaware Memorial Bridge. Thus, Wilmington and the more densely populated areas in the State are located in the Piedmont Plateau region.

Of the 2,399 square miles in the State of Delaware, 1,961 are land and the remaining 437 square miles consist of inland water. In addition to the land and inland water areas, 53 square miles of the Delaware River and 333 square miles of the Delaware Bay are located within the boundaries of the State. The whole width of the Delaware River, to the low-water mark on the New Jersey shore, from the junction of the Delaware-Pennsylvania-New Jersey boundaries, to a point south of Reedy Island, is a part of the State of Delaware. From Reedy Island southward the boundary is located in the middle of the River.

The State is divided into 3 counties as follows: New Castle, 493 square miles; Kent, 806 square miles; and Sussex, 1,100 square miles. Of the total land area of the State approximately one-half is tributary to the Delaware River Basin. A detailed summary of the more important drainage basin areas of the State is shown in Table 1.[1] Thus, it may be seen that 41.3 percent of the State's drainage area discharges into the Delaware Bay and 13.5 percent into the Delaware River. A total of 54.8 percent enters the Delaware Drainage Basin and the remainder eventually reaches the Atlantic Ocean or the Chesapeake Bay.

5.02 GEOLOGIC

The two major physical features of Delaware are the areas of crystalline rocks in the Piedmont Plateau, which is part of the foothills of the Appalachian Mountains, and the Coastal Plain, which is a wide belt of sand, clay, and gravel covering the coastal areas and extending seaward beneath the Atlantic Ocean for 100 miles or more. The boundary between the Piedmont and the Coastal zones, commonly known as the Fall Line, marks the zone of rapids and falls where streams running off the hard crystalline rock descend onto the Coastal Plain. The Fall Line coincides with many of the oldest and most important cities primarily because it is the inland limit of navigation, as well as having been a source of waterpower. The Fall Line acts as a tidal barrier separating the estuary of the river from its headwaters. The Delaware River crosses the Fall Line at Trenton, New Jersey, and from this point downstream is affected by the rise and fall of the ocean tides.

TABLE I

	TOTAL LENGTH OF STREAMS MILES	DRAINAGE AREA SQ MILES	% OF TOTAL DRAINAGE AREA	RECEIVING BODY OF WATER
Nanticoke River	125.4	270	17.0	Chesapeake Bay
Broad Creek[1]	62.9	125	7.9	Chesapeake Bay
Indian River	165.9	310	19.5	Atlantic Ocean
Buntings Branch	7.5	14	0.9	Assawoman Bay (Atlantic Ocean)
Broadkill River	60.3	110	6.9	Delaware Bay
Mispillion River	79.3	125	7.9	Delaware Bay
Murderkill River	63.3	107	6.8	Delaware Bay
St. Jones River	73.6	94	5.9	Delaware Bay
Little River	24.4	27	1.7	Delaware Bay
Dona River	19.5	22	1.4	Delaware Bay
Leipsic River	44.7	68	4.3	Delaware Bay
Smyrna River	63.5	68	4.3	Delaware Bay
Blackbird Creek	29.0	31	2.0	Delaware Bay
Appoquinimink Creek	44.4	47	3.0	Delaware Bay
Christina River	63.1	66	4.2	Delaware River
Red Clay Creek[2]	23.6	23	1.4	Delaware River
White Clay Creek[3]	53.8	45	2.8	Delaware River
Brandywine Creek[3]	36.4	33	2.1	Delaware River

1 Tributary to the Nanticoke River
2 Tributary to the White Clay Creek
3 Tributary to the Christina River

Geologists have surmised[2] that approximately 15,000 years ago, during the last Ice Age, that the level of the ocean was approximately 200 feet lower than at present. At that time the shoreline of Delaware and New Jersey extended farther out into the ocean. Also, at that time, the Delaware River probably flowed due east across New Jersey into what is now Barnegat Bay, and the Schuylkill River similarly flowed east across New Jersey to what is now the Mullica River. A stream, possibly the Brandywine or a combination of the Brandywine, Christina, Red Clay, and White Clay Creeks, also flowed in a parallel direction straight across what is now the lower portion of Delaware or the present Delaware Bay. Geological changes eventually caused the Delaware River to make a 90° turn southward and flow into the Schuylkill. In time both rivers joined the then proto-Brandywine to flow into the presently-known Delaware River channel or Bay. As the water level of the Atlantic Ocean rose, the Delaware Bay broadened to its present state. The Atlantic Ocean is reportedly continuing to rise at a rate of about 1 foot every 50 years.

Other such changes in the course of rivers have been shown[2] in Delaware in the area between Newark and Wilmington. Here, a group of streams running seaward off the crystalline rocks of the Piedmont Plateau has been captured by the Christina-White Clay system, which flows along the Fall Line. The old stream channels, now filled with sand and gravel, can be seen in cuts which were made when the Chesapeake and Delaware Canal was dug, giving evidence of this long-abandoned drainage system.

As the glaciers of the Ice Age melted and receded from the Delaware Drainage Basin, the flow of water in the Delaware River decreased, and the more northerly rivers, such as the Hudson, Ohio, and St. Lawrence, carried most of the water from the melting ice. River silts and even clays were deposited in the quiet waters of the lower Delaware. As the glaciers continued to melt, the sea level rose and drowned that part of the valley so that the lower portion of the River became estuarine and encroached upon its shores to form the bay.

Other authorities[2] believe that after the ice cap melted the sea level stood approximately 200 feet or more above its present level. However, recent examinations of land forms and deposits in Delaware reveal no evidence that the Pleistocene sea level was ever more than 50 feet higher than at present.

In the Piedmont region of northern Delaware, there is no evidence of glaciation. Glaciated lakes which dot the landscape in northern New Jersey, in the Piedmont Plateau region, are conspicuously absent from Pennsylvania and Delaware.

The drop from the Piedmont Plateau to the Coastal Plain is approximately 50 feet. The surface of this region is gently rolling at the intermargin and flattens toward the sea. The soil is typically loose, sandy, unconsolidated, morainic debris, transported by streams from the higher hinterland. This area was once extensively forested, but forests have virtually disappeared from the Delaware Coastal Plain to make room for agriculture. Forest cover exists along stream courses and around the many ponds to be found throughout the State. The Delaware River from the northern Delaware boundary drains approximately 1,000 square miles of Delaware and New Jersey; 282 square miles of Pennsylvania, and approximately 8 square miles of Maryland.

This area represents approximately 20 percent of the entire Delaware River Basin.

5.03 TERRAIN

In Sussex County the highest point appears to be a 71-foot sand dune at Cape Henlopen, north of Rehoboth Beach. There is a 69-foot peak east of Delmar on the Maryland-Delaware State line. The Indian River Basin, located in southeast Delaware, constitutes a low lying area. Georgetown, at the northwestern edge of the Indian River Basin, has a bench mark 56 ft. above sea level. The majority of the land in the Indian River Basin is between 20 and 30 ft. above sea level. Rehoboth Beach is 23 ft. above sea level and Lewes is only 15 ft.

The Indian River Basin is separated from the Nanticoke River Basin by a ridge of about 40 ft. to 50 ft. in elevation extending from east of Greenwood to Georgetown, and another ridge of about 50 ft. in elevation from Georgetown south to the Maryland-Delaware State line. Elevations of 40 to 50 ft. in the southern part of Sussex County prevent this southwest area of the State from being tributary to the Nanticoke Basin. Seaford is at an elevation of 20 to 30 ft., and Laurel is at an elevation of about 20 ft. The 60-foot elevation at Greenwood is the maximum level in the Nanticoke River Basin. A ridge of 50 to 60 ft. separates the Nanticoke from the Marshyhope Drainage Basin to the northwest. The Town of Milton, at the upper limits of tidewater on the Broadkill River, has an elevation of 30 ft. Milford, at the head of the tidal portion of the Mispillion River, is only 9 ft. above sea level.

The eastern edge of Kent County bordering the Delaware Bay consists of a marsh area varying from 2 to 5 miles in width for the entire length of the county. This marsh area is less extensive in depth north to New Castle and south to Lewes. The Bombay Hook National Wildlife Refuge is a marsh area about 5 miles wide, located in the northern portion of Kent County bordering the Delaware Bay. Most of these marsh areas were originally tidal, but many of them have been made fresh water systems or partially fresh water by the installation of tidal gates.

A 60-foot ridge extends northward from Georgetown to Harrington, and from Harrington, at levels of 60 to 70 ft., in a north-northwesterly direction to the western edge of the State to a point where the Chesapeake and Delaware Canal intersects the Maryland-Delaware State line. This ridge separates the Delaware River Drainage Basin from the Chesapeake Bay Drainage Basin. The highest point in Kent County is at Davis Corner, about a mile east of Hartly, at 75 ft. above sea level.

Moving northward from Smyrna River into New Castle County, there is a gradual rise in land elevation. In all cases, however, the land immediately adjacent to the shore of the Delaware Bay is marshy. Between Appoquinimink Creek and the Chesapeake and Delaware Canal, the land reaches a height of 80 ft. above sea level.

The land elevation to the north of the canal rises gradually. A ridge of about 80 ft. separates the White Clay Creek from the Christina, and this rises to about 120 ft. at Newark.

North of Newark, the land becomes hilly and rises fairly rapidly to 300 ft. above sea level. This hilly territory separates the White Clay and Red Clay Creeks.

Centerville is the highest point in Delaware at 438 ft. The City of Wilmington is located at the junction of the Christina River and the Brandywine Creek at 10 ft. above sea level; however, portions of the City are located on land 210 ft. above sea level.

5.04 STREAM CHARACTERISTICS

The Brandywine Subbasin consists primarily of the watersheds of the Christina River, Brandywine Creek, White Clay Creek, Red Clay Creek, Naaman's Creek, Marcus Hook Creek, Chester Creek, Ridley Creek, Crum Creek, and Darby Creek. The 8 square miles of the State of Maryland which are included in this area contain the headwaters of the Christina River and are of minor significance to this report. This subbasin watershed of approximately 800 square miles lies mainly within the Piedmont Plateau. A small portion, particularly that area including the Christina River and southward, is within the Coastal Plain. In general, the Piedmont Plateau is an extensive gently undulating region which slopes southeastward. It is underlain chiefly by Precambrian crystalline rock but in some places by Ordovician Limestone. Ridges of Cambrian quartzite are occasionally found in this area. In this watershed there are about 1,000 acres of ponds and reservoirs, and approximately 580 miles of permanent streams. There are about 2,800 acres of fresh tidal marsh and 200 acres of fresh tidal water. Approximately 2,000 acres of tidal wetland and 200 acres of important tidal waters are located in the Christina River subbasin area. There are almost 1,000 acres of mixed, deep and shallow tidal marshes bordering the Christina in sections between Wilmington and Basin Road, Delaware, Route 41.

The Brandywine is the only typical mountain stream in Delaware. The elevation at the point where the Brandywine enters the Delaware from Pennsylvania is approximately 150 ft. above sea level. Closer observation of the elevation in the Brandywine shows that at the junction of the East and West Branches in Pennsylvania, a short distance below Wawaset, the elevation is 180 ft. At Rockland, 13.2 stream miles downstream, the elevation is 130 ft. This relatively flat section constitutes a drop of 3.78 ft. per mile. In contrast, the change from Rockland to the Wilmington USGS gaging station, a distance of 2.3 miles, constitutes a fall of 26.9 ft. per mile. This change is approximately seven times that of conditions upstream from Rockland.

Appreciable segments of the major drainage basin, within the State of Delaware, are subject to tidal effects. The percent of each stream which is tidal is shown in Table 2. The area drained by the tidal portion of the stream is roughly equal to the area drained by the nontidal upstream segment.

The headwaters of the Broadkill River have their origin in the bog area north of Georgetown. During the late thirties a large mosquito control project was completed in the marsh area north of Broadkill River. A drainage ditch was so constructed that drainage from Reynolds Pond,

Waples Pond, and Prime Hook Creek was diverted into the Broadkill River at a point 4.5 miles from Roosevelt Inlet.

5.05 WETLANDS

The State of Delaware is predominantly located, approximately 95 percent, in the Coastal Plain. All the wetlands[3] are located in this Coastal Plain.

These wetlands are concentrated along the coast. The gentle fall of the upland to the coastline is conducive to an intensive agricultural land use, and any wetlands naturally in this area were long ago reclaimed for agricultural use. The major portion of the coastal marshes is formed behind barrier beaches and extends inland for varying distances, depending upon the elevation of the adjacent upland.

There are three general types of coastal marsh regions in this State. The first lies north of the Chesapeake and Delaware Canal, and in this region the marshes are almost entirely fresh due to the influence of the less saline portion of the Delaware River. The second region lies in the area from the Canal south to a point near the St. Jones River. In this region from north to south the fresh water in the Delaware River has less effect on the wetlands, and the saline water of the Delaware becomes exceedingly complex. The third region is roughly the lower third of the State. The majority of the wetlands is the coastal saline type and primarily cordgrass marshes.

The Fish and Wildlife Service[4] has set up a classification system for the wetlands of the United States. The 4 main groups are: (1) inland fresh, (2) saline, (3) coastal fresh, and (4) coastal saline. Of the 20 wetland types in the United States, only 6 are important in Delaware: the inland fresh wooded swamp type and 5 coastal types. Seven other types are also found in the State but in insignificant amounts. The total area of wetlands in Delaware is 131,275 acres. Further detail can be found in Section XX, prepared by the Game and Fish Commission.

5.06 SUMMARY

Distribution of surface waters within Delaware varies throughout the State. Excluding the Delaware River, the land and water area of the State totals 2,100 square miles. Of this, approximately 435 square miles are continually subjected to saline water. Approximately 276 square miles of the State drain into the Chesapeake Bay.

Many streams in Delaware, particularly in the lower portion, have their origin in swamps or bogs. Within the flat lands in the Coastal Plain areas, the slope of the streams is very small.

Within Delaware, excluding the marshlands, there are approximately 327,000 acres of imperfectly and poorly drained soil. Of these, roughly 21,000 acres are in New Castle County; 100,000 acres are in Kent County; and 206,000 acres are in Sussex County. These figures include both farming and woodland.

Drainage is a problem for at least 25 percent of the State. The problem is further complicated by the fact that these poorly drained lands occur in scattered areas.

TABLE 2

DRAINAGE BASIN	PORTION TIDAL (In percent)
Nanticoke River	30
Broad Creek[1]	41
Indian River	64
Buntings Branch	5
Broadkill River	69
Mispillion River	64
Murderkill River	67
St. Jones River	61
Little River	85
Dona River	90
Leipsic River	70
Smyrna River	84
Blackbird Creek	80
Appoquinimink Creek	63
Christina River	47
Red Clay Creek[2]	0
White Clay Creek[3]	0
Brandywine Creek[3]	11

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1. Water Pollution Commission, State of Delaware, Dover, Del. Eighth Annual Report (1956-58)

2. Ward, Richard F., "Geology of The Delaware." Estuarine Bulletin, University of Delaware, Autumn, 1958, Vol. 3, (Sept. 1958).

3. Wetlands Inventory of Delaware, U.S. Dept. of the Interior, Fish and Wildlife Service, Office of River Basin Studies, Boston, Mass. (Nov. 1953).

4. Sub-Basin Report #10, Brandywine Area, Prepared By U.S. Fish and Wildlife Service as Part of Report of Fish and Wildlife Sources.

SECTION VI -- SUMMARY REVIEW OF WATER RESOURCES PLANNING

6-01. GENERAL

Water resources planning within the Delaware River Valley has been under active consideration for more than 30 years. The City of New York has not only planned but has also constructed various reservoirs within the State of New York on the upper reach of the Delaware River. Before construction could be undertaken and the diversion of water out of the basin permitted, two cases were heard in the U.S. Supreme Court in 1931 and 1954. Incodel in 1950, proposed a detailed plan for the harnessing of Delaware River water and the supplying of augmented flow. After approval by New York, New Jersey, and Delaware, in February, 1953, the Pennsylvania Water Resources Committee recommended that the Incodel plan be rejected, which was adhered to by Pennsylvania.

The above incidents are reviewed in detail in reports submitted by several Federal agencies, including the Public Health Service. However, it was deemed pertinent for the purpose of being comprehensive that a brief resume of these incidents be summarized herein.

6-02. SUPREME COURT DIVERSION CASE OF 1931

The New York State Power and Control Commission in 1929 approved a plan to develop and divert waters of the upper Delaware River tributaries. It was planned that the completed project be consummated by 1939 and provide 700 million gallons per day (mgd), of which 600 mgd would come from the tributaries of the Delaware River.

The State of New Jersey applied to the U.S. Supreme Court to enjoin the State and City of New York from diverting any of the waters of the Delaware River. Pennsylvania became a party of the suit as intervener to protect its rights to the Delaware River as a future supply. New Jersey took the position that the diversion would cause substantial damage to navigation, water-power, sanitary conditions of the river, industrial use, oyster and shellfisheries, municipal supplies, agricultural lands, and recreation. A Special Master heard the case and the findings were approved by the Supreme Court on May 25, 1931. The decision (1) limited the City of New York to a diversion of 440 mgd; (2) specified that New York release from the reservoir a limited quantity of water to maintain certain minimum flows within the Delaware River, and (3) directed that an effective sewage plant for Port Jervis be constructed before any diversion could be made. The decree also permitted New York City to petition for an additional diversion at a future date.

6-03. INCODEL PLAN

In the fall of 1950, Incodel presented its "Report on the Utilization of the Waters of the Delaware River Basin," which contained a plan for the water supply development and flow regulation in the entire Delaware system. In the final analysis the Incodel plan recommend-

ed two alternate plans which differed basically in their method of supplying Philadelphia and adjacent areas with additional municipal and industrial water.

The major purpose of the Incodel Study was to formulate a plan for an integrated interstate development of the Delaware River for the four states represented on the Commission; namely, New York, New Jersey, Pennsylvania, and Delaware. The overall recommended plan designed to serve the needs of the four-state areas, would be implemented in two or more stages. Stage 1 was designed to provide up to 465 million gallons of water daily to meet the requirements of the northern New Jersey and New York areas for the next 30 years. This amount is over and above the 440 mgd previously granted by the Supreme Court. The first stage would also provide for the storage of sufficient water to maintain a minimum flow in the Delaware River at Trenton of 4,000 cubic feet per second (cfs) without the construction of a reservoir at Wallpack Bend, and 4,800 cfs with a reservoir at Wallpack Bend. The reservoirs would retain lakes of about 1/3 reservoir depth in the driest years. Alternate (A) would be the system without a reservoir at Wallpack Bend, and alternate (B) is a similar system but with a reservoir at Wallpack Bend. Each of these projects was designed individually so that allocations anticipated for water supply and flow regulation could be made. In alternate (A), which does not include Wallpack Bend, an allocation of costs was designed for stream flow regulation to the four benefiting states. A similar breakdown was given for alternate (B) of stage one with the Wallpack Bend reservoir. In each instance, the State of Delaware was allocated 5 percent of the total benefits involved. This allocation for Delaware amounted to \$226,000 and \$338,000 annually, respectively.

The Incodel plan if completed would, in addition to its water supply aspects, result in a river which would be more suitable for both municipal and industrial purposes. Increased flows in the summer and fall, when most needed, would facilitate the assimilation of effluents from sewage and industrial waste treatment plants. At the same time recreational opportunities, as afforded by the river, would be enhanced while waterfront property values also would increase. The plan further stated that the greatest benefits from this feature of the project, however, would accrue to the heavily industrialized sections of Pennsylvania and New Jersey, between Philadelphia and Wilmington, and to the oyster and shellfish industry in the Delaware River and Bay along both New Jersey and Delaware shores.

An Incodel Compact, encompassing the Incodel Plan, was a measure which would provide for an interstate agency to construct and operate the proposed Incodel Reservoir Project. This Incodel Compact was introduced in 1951 into the Legislatures of Delaware, New Jersey, and New York. It was passed at the same sessions by the States of Delaware and New Jersey; New York deferred passage until 1952, awaiting action by Pennsylvania. Pennsylvania, however, was not willing to have the Legislature consider the matter until a committee named by its Governor had made an independent appraisal of the program.

While Pennsylvania's Water Resources Committee was evaluating the Incodel Plan with respect to its benefits, New York State passed the proposed Incodel Compact in 1952. In 1952 the City of New York filed a petition with the Supreme Court seeking approval to proceed with its independent plan to develop the Cannonsville Reservoir on the West Branch of the Delaware River for the purpose of securing additional water supply. This independent action was taken by the City of New York since it took the position that it could not wait any longer for the Pennsylvania Water Resources Committee to provide its re-evaluation decision.

6-04. PENNSYLVANIA WATER RESOURCES COMMITTEE REPORT

In February 1953, the Pennsylvania Water Resources Committee rejected the Incodel Plan on the basis that it felt Pennsylvania would not derive sufficiently important benefits for low-flow augmentation to compensate for the total diversion by other states of an additional 930 mgd from the Delaware watershed. Other objections were also raised by Pennsylvania in regard to future water allocations.

This Committee was set up by Pennsylvania to examine the Incodel Report. Its purpose was to determine whether Pennsylvania should participate therein or to adopt some modified form of such a plan to make a preliminary study of the water resources available to southeastern Pennsylvania. The study was confined solely to the advantages and disadvantages which would accrue to this area of Pennsylvania, largely without regard to the adjacent states. General conclusions drawn were that insofar as water supply is concerned, the Incodel Plan would only benefit New York City and northeastern New Jersey, areas outside of the watershed, unless and until the City of Philadelphia embarks upon a major and costly program of going upstream for this water supply.

Insofar as the other major element of the Incodel Plan is concerned, namely, augmentation of low river flow, the conclusions of the Committee were that the overall effect would be slight. The frequent and increasing salinity invasions in the lower river area would not be eliminated, little improvement to the oyster or fishing industry would result, and the recreational features would largely be a benefit to an area of New York State, far removed from Pennsylvania residents. The above findings resulted in a recommendation that Pennsylvania should not become a part of the Incodel Compact.

A Pennsylvania Water Resources Committee recommended that if Philadelphia and southeastern Pennsylvania find it necessary to acquire upland water, Pennsylvania, New Jersey should enter into an agreement to construct Wallpack Bend reservoir. This suggestion was followed in 1954 when the New Jersey Legislature enacted a law which repeals a 1783 statute that forbids the construction of dams on the Delaware River. At the same time it permitted New Jersey to enter an agreement with Pennsylvania f[illegible] such construction. Of particular interest, the law confirmed the [illegible]ght of New Jersey to divert 100 mgd from the stream and limited New Jersey's contribution to the joint project to 30 percent.

6-05 THE SUPREME COURT DIVERSION CASE OF 1954[1]

The formal opposition by New Jersey, Pennsylvania, and Delaware to the petition of the City and State of New York requesting further diversion of water from the Delaware to the U.S. Supreme Court was filed April 1, 1952. The City sought to construct the third stage of the Delaware River supply with a reservoir on the West Branch at Cannonsville and to increase its 440 mgd diversion from the Delaware watershed, which was authorized in the decree of 1931, by 360 mgd, making a total of 800 mgd. The Court's decision was rendered on June 7, 1954, approving an amended decree. In securing this additional amount, the new decree specified that the water will be released from the City's reservoirs during low flow periods in accordance with the "Montague Release Formula". This formula provides for the maintenance of certain minimum flows in the river at Montague, New Jersey, and, in addition, make supplementary releases, depending upon the City's ability to make them when consumption is less than a safe yield, without pumping.

The safe yield, following completion of the proposed Cannonsville Project, was estimated at 1,665 mgd.

Testimony and exhibits were presented on both sides before the Special Master appointed by the Court on June 9, 1952. The Master's report, which recommended an amended decree, was filed with the Court on May 27, 1954.

The Supreme Court considered: the amended petition of the City of New York and joined by the State of New York, for which was appended the consent of the State of New Jersey; the answer filed by the State of New Jersey seeking affirmative release; the answers filed by the Commonwealth of Pennsylvania and the State of Delaware; the evidence and exhibits adduced by the parties; and the report of the Special Master. Briefly, the Court:

(1) Approved the report of the Special Master.

(2) Set aside the 1931 decree.

(3) Enjoined diversions by the City of New York except as authorized in the amended decree.

(4) Ordered that treatment must be provided at Port Jervis to effect a reduction of 85 percent in the organic impurities and further treated with a chemical germicide.

(5) Ruled that diversions by New Jersey must be authorized under

[1] Water Works Engineering, "New York's Delaware River Case Decided by U.S. Supreme Court", Anon, (July 1954).

specific conditions; namely, that the State of New Jersey may divert outside the Delaware River watershed from the Delaware River or its tributaries in New Jersey without compensating releases the equivalent of 100 mgd; that the diversion by New Jersey from the Delaware River shall be made under supervision of the River Master and shall be subject to specific conditions outlined.

(6) Reiterated that the existing uses are not affected by the amended decree; namely, that the parties to this proceeding shall have the right to continue all existing uses of the waters of the Delaware River and its tributaries, not involving a diversion outside the Delaware River watershed, in a manner and at locations presently exercised by municipalities and other governmental agencies, industries or other persons in the Delaware River watershed in the States of New York, New Jersey, and Delaware, and the Commonwealth of Pennsylvania.

(7) Ordered that a River Master shall be appointed by the chief hydraulic engineer of the U.S. Geological Survey.

(8) Ruled that no diversion herein allowed shall constitute a prior appropriation of the waters of the Delaware River or confer any superiority upon any party hereto in respect of the use of those waters. Nothing contained in this decree shall be deemed to constitute an apportionment of the waters of the Delaware River among the parties hereto.

(9) Set forth this as a decree without prejudice to the United States. It is subject to the paramount authority of Congress with respect to commerce on navigable waters of the United States; it is subject to the powers of the Secretary of the Army, and the Chief of Engineers of the United States Army in respect to commerce on navigable waters of the United States.

(10) Ruled that, "any of the parties hereto complainant, defendants or interveners, may apply at the foot of this decree for other or further action or belief, and this Court retains jurisdiction of the suit for the purpose of any order or direction or modification of this decree, or any supplemental decree that it may deem at any time to be proper in relation to the subject matter in controversy. The fact that a party to this cause has not filed exceptions to the report of the Special Master or to the provisions of this decree shall not estop such party at any time in the future from applying for a modification of the provisions of this decree, not withstanding any action taken by any party under the terms of this decree."

It is this particular segment of the decree that is extremely important in view of the comprehensive evaluation of the problems in the future within the Delaware River Basin.

(11) Ruled that cost of this proceeding be borne by the various states in the following proportions: the State of New Jersey, 26 2/3

percent; the State of New York, 10 percent; Commonwealth of Pennsylvania, 26 2/3 percent; and the State of Delaware, 10 percent.

The present comprehensive Water Resources Survey covers a period of review (50 and 100 years hence) much greater than has been previously considered by other planners. This significant approval in itself will induce sharp focusing upon the various needs and problems far more than was evident heretofore. Secondly, considerably more detail of water quality and affected interests have been investigated and studied in the past several years. These are significant points which may alter previous conclusions with regard to water use and water planning.

SECTION VII

STATE COORDINATION ORGANIZATION

7.01 INTRODUCTION

Governor Boggs on October 17, 1956, forwarded a letter to the various affected State agencies and other interests, requesting that they cooperate fully in presenting Delaware's need in relation to the U.S. Corps of Engineers Delaware River Valley water study. The Governor further requested that agencies and others submit their specific reports through the office of the State Coordinator, Mr. J. Gordon Smith, Chairman of the State Highway Department, so that the full interest of the State of Delaware could be more completely realized.

The task of coordinating Delaware's statement, with respect to water resources, into a single report was assigned to Mr. Richard A. Haber, Chief Engineer of the State Highway Department. Mr. Haber requested of the Water Pollution Commission, that Dr. A. Joel Kaplovsky, its Director, assist in this coordinating effort. Mr. Haber assigned his Research Engineers, Mr. Chauncey O. Simpson, to assist on the committee. Mr. Haber, as State Coordinator, and Dr. Kaplovsky and Mr. Simpson, as alternate State Coordinators, represented the State of Delaware at the Coordinating Committee meetings called by the Corps of Engineers of the Philadelphia District.

During the first meeting of the State Coordination Committee, it was instantly apparent that there is no simple procedure of determining Delaware's potential growth and water needs 50 and 100 years hence. The situation is further complicated by the fact that no single agency, interest, or group of agencies or interests in Delaware represents the numerous State interests. In addition, no coordinated plan of action to guide Delaware's growth and/or expansion exists. It becomes imperative, and reasonable, that the State of Delaware must be in a position to review the potentialities and/or expectancies of its various interests on a Statewide basis before individual findings or reports can be made pub[illegible] or subjected to interstate evaluation. In order to overcome these dif[illegible]ulties a procedural plan was needed for the State Coordinators to follow in evaluating the various interim reports prepared by other agencies encompassing problems within the State of Delaware whereby fuller knowledge of Delaware's water resources problem would be known. Finally, a unified report should be submitted integrating the work of the numerous commissions, and interests, thus compensating for the absence from our present governmental structure of provisions for a coordinated state effort with regard to assembling water resources information. This coordinating procedure was deemed appropriate in order to prepare an intrastate water resources survey report as an appendix to the Corps of Engineers Report.

7.02 GOVERNMENTAL AGENCIES AND OTHER INTERESTS

Twenty-eight specific interests were involved, represented by various commissions, governmental bodies, and others.

a. State level.

(1) Public Archives Commission
(2) State Board of Agriculture
(3) Office of the Attorney General
(4) Civil Defense Advisory Council
(5) University of Delaware, Civil Engineering Department
(6) Delaware State Development Department
(7) State Forestry Department
(8) Board of Game & Fish Commissioners
(9) Delaware Geological Survey
(10) State Board of Health
(11) State Highway Department
(12) Delaware Interstate Highway Division
(13) University of Delaware, Marine Laboratory
(14) State Park Commission
(15) The Public Service Commission
(16) Delaware Commission of Shell Fisheries
(17) Soil Conservation Commission
(18) Delaware Unemployment Compensation Commission
(19) Delaware Waterfront Commission
(20) Water Pollution Commission

b. County level

(1) New Castle County Levy Court
(2) Kent County Levy Court
(3) Sussex County Levy Court
(4) New Castle County Zoning Commission
(5) Regional Planning Commission of New Castle County

c. Municipal level

(1) Wilmington Water Department

d. Miscellaneous interests

(1) Delaware State Chamber of Commerce, Inc.
(2) Miscellaneous industrial interests

7.03 PRELIMINARY REVIEW

The Corps of Engineers of the Philadelphia District published a loose-leaf book, issued November 8, 1956, and known as the "Data Book", outlining certain basic information needed by the Federal agencies and others cooperating in the preparation of the report and appendices on the comprehensive water resources survey of the Delaware River Basin. The Data Book provides a procedural plan, assigning to each of the Federal agencies certain problems which are to be investigated in the study.

After reviewing the Data Book the procedural plan for the survey of the Delaware River Basin Water Resources, the State Coordinators decided that the needs of Delaware could best be served in an expeditious manner by following a slightly modified approach to the Corps of Engineers procedural plan.

It is well understood that water requirements in the future are dependent upon growth and development. In order to accelerate the flow of information, it appeared advantageous initially to obtain an insight on the scope and magnitude of the problems. Therefore the various interests in the State which would be affected directly or indirectly by water availability were requested to express, in brief letter form, the potentialities and possibilities confronting their specific field 50 and 100 years hence.

In a letter dated December 19, 1956, Mr. Haber, the State Coordinator, requested the various State Commissions and interests to procede with the modified approach. Each interest was directed to assume that sufficient water would be available for its specific phase. In this way, the question of water availability was temporarily removed so that each could express more candidly their potentialities and expectations. These brief letter estimates would, of course be extremely preliminary and further details or clarification would be developed in personal conferences. These "crystal ball" statements, when critically analyzed could conceivably provide the basis for establishing, within reasonable limits, the expected growth. However, if expected growth were established and used as a guide each participant would save considerable time in preparing his detailed reports. This would also serve to standardize the raw materials used in the report and make it easier to orient the common effort. Normally, the type of information needed for compiling an overall report on the State's needs would require many rewrites, since the future expansion or growth pattern is dependent upon many variables of which the participants may not be fully cognizant. A tremendous saving of time could be achieved if the Coordinating Committee could obtain sufficient information from the letter-reports and set forth a considered potential growth within 50 and 100 years hence. In this way, rewrites of reports from each of the interests could be kept to a minimum.

This expeditious approach would provide several additional advantages.

1. Each of the interests would have an opportunity to express itself.
2. Each interest would provide growth details in the field of endeavor in which it is best qualified.
3. A single detailed report would be sufficient from each of the interests, since all reporting would be based upon the same fundamental series of measures such as population, water availability, industrial growth, and land availability, etc.

Based upon the above procedure each of the commissions and interests was contacted by the State Coordinators during the month of January 1957. Cooperation from the various interests was extremely good. The letter reports received were interesting, informative and enlightening. Surprisingly these "crystal ball" forecasts from diversified interests showed marked agreement, indicating that foresight and forethought can eliminate future difficulties.

The letter reports indicated that both industry and population expansion will continue to increase at a very rapid pace, at least for the next 50 years. Further, the rate of growth of industrial development will be notably greater than the rate of change of population. Water and land availability will, in all probability, be the two primary factors governing any growth or expansion in the future.

With the increase in the growth of the State, water availability will become the more critical issue. In anticipation of the ever-increasing public demands for additional recreational facilities, extension of wildlife areas, the expansion of commercial fishing, improvement of residential areas, and rural beautification, the air and water quality will become increasingly important. Air pollution control will certainly become a major issue and may become a controlling or limiting factor to expansion. Pollution control will also become a major factor in determining whether industrial, shellfish, and recreational areas can exist within the shadows of each other.

Several of the reports implied that available land will become one of the critical issues in the near future, therefore it is appropriate that a careful review of the overall land usage pattern be considered for the present, for the year 2010, and for the year 2060. It can be reasonably inferred that we have enough land available to meet the expected maximum growth pattern in the next 50 and 100 years. However, it is also obvious that certain interests will, for economic reasons, compete for this needed land area.

Many future land areas needed for special purposes will not be available at specific desirable locations. Conflicting views will arise in the use of these available land areas. In order to provide for the best benefits for the people of the State of Delaware, the problems relating to the future use of specific land areas must be resolved on a one-use or multiple-use basis.

The primary objective of this survey is to obtain information with respect to water needs for the State of Delaware in the next 50 and 100 years. It is absolutely essential that the estimated maximum water needs be established and that water sources be made secure. Sufficient water supply will not always be available at each land area to be developed, hence the cost and problems of distribution may limit our future growth. It would be extremely unwise for the State of Delaware to be too conservative or casually minimize its future water requirements in relation to the water supply available in the Delaware River Valley. Good judgment demands use of a proper safety factor in estimating future requirements since "available water" is not necessarily "attainable water", economically speaking.

The above details were discussed at a general State coordinating meeting held in Dover, May 27, 1957, at the request of Governor J. Caleb Boggs with all interested agencies and others participating in this survey.

7.04 THE ASSIGNMENT OUTLINE

The State Coordinators prepared for distribution an Assignment Outline which fully elaborated on the purpose of the survey and directed specific questions to interested groups. The agencies were to prepare their reports on the basis of these questions. However, although it was specified that the questions were pointed to certain information required by the Coordinators, the agency had the privilege of expanding its contribution to include information pertinent to the problem, but which had not been included in the assignment outline.

As a guide in preparing detailed reports having continuity, various interests were informed on the following conditions:

a. The population of the State of Delaware in the year 2010 will approximate 1,400,000.

b. The population for the State of Delaware in the year 2060 will approximate 3,500,000.

c. Sufficient land area will be available for each of the interests of the State with respect to farming, recreation, fish and wildlife, industry, highways, cities, and residential development.

Detailed reports prepared under the above specified conditions would provide the basis for estimating the actual water needs, within limits, 50 and 100 years hence. Simultaneously, those interests concerned would be pinpointing the area of need. In this way, water requirements of the future for the State of Delaware may be established, coupled with the inherent limitations attributable to distribution and the economics thereof.

The Assignment Outline contains many primary questions which, if answered, would assist in the preparation of a comprehensive report for the State of Delaware. The outline listed over 100 questions which were submitted to the appropriate governmental agencies and other interests of the State. The Coordinators sent to the agencies only those questions which applied or were related to the field of work of the agency, but many of the inquiries applied to several agencies; in such cases the responses were especially useful. By this method the State Coordinators endeavored to obtain information on certain problems from different perspectives.

In presenting these basic questions it was realized that some information would not be available, but it appeared prudent to seek out the deficiencies so that measures could be taken in the future to supplement incomplete data.

The requests covered, in the main, present water requirements, present land uses, population, rainfall, storms, existing natural drainage conditions, chemical qualities of the tributaries, water availability from surface and ground water sources, problems of flood control, utilization and conservation of water future, land use patterns, future population, future water requirements, possibility of obtaining water from outside the basin, study of the Delaware River and Bay, economic studies and, legal aspects.

In order to establish a firm foundation it was evident a present water use inventory had to be made. Questions were posed to determine: present demands on public and private water systems, covering domestic, commercial and industrial use and other uses which included domestic and farm use, irrigation, recreation, and fish and wildlife.

Associated with this problem is land use. Inquiries were submitted to determine present lands used for industry, agriculture, wildlife, recreation, forests, urban development, suburban development, transportation facilities, highways, etc.

The Coordinators also sought the reasons for the present pattern of land use. What underlying natural geophysical factors created the land use as it exists today in Delaware? As part of this problem it was pertinent to know the effect of different land uses upon drainage.

One of the major problems for which answers were sought concerned expected future populations. The answer to this problem affected all decisions for future water projections. The method of [illegible] was to consider what would be the factors acting as population generators. Will the influences of geophysical factors continue to act as in the past? What effect will industry have? Will railroads and other private transportation systems continue to exert their influence? The effect of the establishment of new industries, of new interstate highways, of changes in agricultural procedures will need consideration. The influence of the beach recreational area is deemed important. In addition, the automation of industry and the availability of labor must be analyzed. Last but not least, a possible change in the State's tax structure and the use of nuclear energy in power production also must be considered.

In order to resolve the future water supply, inquiries were made regarding rainfall in the various tributary basins in the State. What is the rainfall distribution in Delaware and the basins. To answer this question inquiries had to be made into the study of the erratic nature of past storms, especially the hurricane patterns and possible shifts of the pattern. The need to establish stream and rain gages to obtain data for use in future study; the rainfall-runoff relationships; the frequency of peak discharges; the duration and magnitude of maximum high and minimum low flow. The quality of water is associated with the study of stream flow. Other questions were directed to investigate industrial wastes and sources of pollution and sediment due to erosion.

Flood control is associated with the study of streams and flood-plain zoning. What type of construction can effectively control excessive runoff, such as [illegible] dykes, walls, etc? What is the effect of channel improvement? What is the loss to agriculture due to inundation? The study of past flood damage thus came into the picture, as well as the need to establish flood warning systems.

In order to study future water needs inquiries were posed regarding projected agricultural practices such as irrigation to increase farm production; the future demand for good water for recreational use; the industrial use of water; the handling of pollutants, and the determination of future domestic demands.

Future land use must be considered. What portion of the land will be farms, farm forests, forest farms, incorporated municipalities, residential suburbs, industrial sites, canals, swamps, military reservations, highways, recreation areas, marshes, and unuseable water areas.

The results of the study should determine the future needs and the availability of surface water and ground water in the state.

If the final answer establishes the fact that a deficiency of water will exist in the future, what joint action should be taken by the agencies to assist in relieving the situation? Would intensified forest management and reforestation be effective in changing the runoff rates? Would the construction of small dams provide water for irrigation? What methods should be provided for the ever-increasing quantity of industrial wastes? What possible multiple uses of water may serve several interests? What improved soil conservation techniques should be used to prevent sedimentation in stream and increase ground water recharge? Will dilution be satisfactory for treating pollution?

The use of dams to store excess water occurring at certain periods of the year, thus augmenting the supply should be considered. Where should these dams be located? Consideration should be given to the schedule such structures should be built. What are the possibilities for mediate purchase of lands for future reservoir sites in order to obtain the sites and lower future costs?

What sites should be avoided for water supply structures in order to accomplish the preservation of historical and archeological sites in the State?

If the water supply within the State proves to be insufficient to meet the future water needs, where can it be obtained outside the State? What will be the possibility of obtaining waters from the fresh-water stretch of the Delaware River?

The study of the Delaware River and Bay is quite important. What is the effect of water diversions in regions upstream upon uses in the State of Delaware? What are the fresh water requirements to maintain a satisfactory oyster environment? What are the effects of uncontrolled flows upon the ecology of the Bay? What is the pollution load being discharged into the tidal stretch and its effects? What are the effects on ground water sources of deepening channels in the Chesapeake and Delaware Canal and in the Delaware River? Attention must be given to the future hazards of industrial wastes from nuclear power and associated manufacturing plants. What is the effect of a change in sea level and how does it relate to the various problems?

From the results of the study there must be developed several alternate plans to accomplish the desired end. What will be the cost and the benefits of each plan? Will such a plan enhance the land? How should the costs be prorated among the interested agencies and interests? Can the future economy of Delaware be divided into two regions, one of which drains into the Delaware River and the other into the Chesapeake Bay?

Of all the problems connected with this survey which must be resolved if any future plan for supply water to the State is to be successful are the legal problems. Any plan developed for the Delaware River Basin must include cooperation with the States of Pennsylvania, New York, and New Jersey. All levels of government will be involved, ranging from the Federal Government to the county units and incorporated towns and cities. We have in this complex drainage unit of nature an existing heterogenous body composed of many political entities which operate under different laws, regulations and thought. Blending these governments into a homogeneous legal system is a monumental task but not insurmountable.

Some of the more pertinent legal queries are as follows: What are the present Federal and State water laws and policies? Who will control the development of storage facilities and control the sale of water? As the total plan will include hydrolectric power, how will Delaware be affected? Who will control pollution and to what extent? What arrangements can be made for controlling land use practices to overcome sedimentation? What consideration can be given to flood plain zoning for the Delaware River and its smallest tributaries to prevent damage and loss of life? To what levels of government shall these problems of flood plan zoning and land planning be assigned? Study riparian rights on small streams and consider whether legislation is needed to modify existing law. What regulations might be required to control ground-water use? What authority will be needed to control the financial operations if a satisfactory plan is chosen? What authority will be responsible for land acquisition and transfer or disposal? What authority will administer construction? Who will conduct operations and maintenance? Who will administer licensing? What authority should have control over the water resources and to what extent? What new water resources laws should be legislated to protect all interests?

The questions and problems presented to the agencies and other interests in the Assignment Outline were the result of a study of the Corps of Engineers Data Book in which were designated the subjects to be covered by the Corps of Engineers and the Federal Agencies cooperating in the study. Investigating similar problems in the State and relating them to the Corps of Engineers Report would result in a coordinated effort.

The State agencies and others participating in the survey were provided with a copy of the Data Book which, in addition to outlining the work of the Corps of Engineers and other Federal agencies, set forth instructions for the physical makeup of the reports, plans, and charts in order that there be uniformity in the presentation.

Our interests indicated a mutual consultation on the common problems in order that a unified State report be presented to the Corps of Engineers, and this was done.

7.05 COORDINATION ACTIVITIES

The State agencies and others interested were requested to present preliminary drafts not only for review by the Coordinators, but for distribution amongst the other agencies for their review and comments. Copies of drafts were forwarded only to those agencies whose problems were allied with the activities of the author agency. Copies were made of all comments received and forwarded to the author agencies for consideration in revising the reports in final draft form. Final drafts received were retyped on multilith plates for the use of the Corps of Engineers in publishing the State report as an appendix to the Federal report. Reproductions were made of all tracings which were sent to the Corps of Engineers with the multilith plates

The Corps of Engineers sent the Coordinators Federal reports on the following subjects: forestry, irrigation, fish and wildlife, multipurpose reservoirs, recreational resources, economic base surveys, municipal and industrial water use, soil conservation, weather, general geology, ground and surface waters, sedimentation and related general hydrology, water needs and their relation to storage at projects for the control of surface runoff, selection of the basic plan for control and utilization of surface waters of the Delaware River Basin, hydrology of the Delaware River, and many others. Copies of these Federal reports were requested and obtained for the appropriate State agencies to which the subject matter applied. The State interests reviewed the Federal reports and the comments were sent to the State Coordinators who drafted a reply to the Corps of Engineers. The Coordinators completely reviewed and replied in detail to all Federal reports received.

The State Coordinators attended all the meetings of the Delaware Basin Survey Coordinating Committee, which were held at locations available and convenient to members and others working on the survey. The meetings were divided into two sessions, a work session for committee members, their alternates and representatives of their staffs, and a session for the submission of reports, review of the progress of the work, and general discussion.

The State Coordinators prepared statements for these meetings, as requested by the Corps of Engineers, and these reports are contained in the section VIII entitled, "Statements Made at Various Coordinating Meetings."

Minutes were published of each meeting through the chairman of the committee, who was the District Engineer of the Corps of Engineers, U. S. Army District, Philadelphia. Copies of the Coordinators' statements and minutes of the meetings were distributed to State agencies and allied interests.

During the survey the Corps of Engineers conducted a hearing in Wilmington with regard to the feasibility of a barrier dam in the Delaware River. The Delaware interests actively participated in the meetings. (see Section XXIII)

The State Coordinators held many conferences with the writers of reports for the purpose of clarifying and collating questionable points and to eliminate as far as possible conflicting statements. They found it necessary to prepare sections of the report which were either nonapplicable to a specific agency or data was not readily available. The Coordinators prepared the initial reviews, discussions and observations and their staff edited all reports and typed all master copies.

SECTION VIII

STATEMENTS MADE AT VARIOUS COORDINATING MEETINGS

8.01 GENERAL

The first meeting of the Delaware Basin Survey Coordinating Committee was held April 2 and 3, 1957. At that time the State of Delaware was requested to make a statement with regard to the Survey Report. At each succeeding meeting similar requests of Delaware were made. On occasion a report of progress was required. However, on other occasions commentary was desired on specific subjects under consideration by the Corps of Engineers Survey group.

It is deemed appropriate and within the scope of this report for the readers to be fully acquainted with the statements and/or position taken by the Delaware State Coordinating Committee. Therefore, the formal comments made at each meeting are included below.

8.02 MEETINGS

a. First meeting. At the April 2 and 3, 1957, Coordinating Committee meeting held at Atlantic City, New Jersey, the following general statement was made by representatives of the State of Delaware:

"We, in Delaware, are fully cognizant of the importance and magnitude of the new comprehensive survey of water resources in the Delaware Valley being conducted under the direction of the U.S. Corps of Engineers. The impact of this survey upon Delaware is by no means localized, as compared to our neighboring states, and has tremendous bearing on the future development of Delaware. Our position is more significant, because our entire State and all of its interests are vitally concerned.

"The number of people residing in the Valley total approximately $5\frac{1}{2}$ million, of which total Delaware contributes only 400,000 or approximately one-fourteenth. Area-wise our 2,000 square miles constitutes one-sixth of the total Valley. However, 90 percent of the 400,000 population resides in the drainage basin and over 50 percent of our 2,000 square miles is tributary directly to the Delaware River and Bay.

"On the basis of growth rate, the position of Delaware is indeed unique. The U.S. Census Bureau in Washington has estimated that in the first six years of this decade Delaware has experienced a population increase of 26.4 percent. The Bureau also stated that the population of the Nation climbed only 10.9 percent during the same period. Only four other States showed a percentage higher than that of Delaware; namely, Nevada with 54.6 percent, Arizona with 41.0 percent, Florida with 36.0 percent, and California with 26.9 percent. This increase becomes even more significant when one evaluates the rate of growth in our New Castle County, an area of approximately 500 square miles. By any index, whether it be

population, construction, retail sales, or transportation tonnage, one will find that New Castle County is the fastest growing County east of the Mississippi; and second only to Los Angeles County, California, nationally.

"The Lower Delaware Valley will become, in not too many years, the oil refinery center of the entire nation. We have already taken a tremendous step in this direction as typified by the new $200 million oil refinery at Delaware City.

"On the lower Delaware River and Bay our oyster industry is valued at $56 million, and New Jersey has a corresponding valuation of approximately $60 million.

"The Bay area and its tributaries support a rapidly expanding commercial fishing industry with a minimum potential income of $100 million per year.

"In view of the fact that the entire State of Delaware is enveloped in this rapid growth, we have been confronted with a special problem. The pattern of growth has affected, either directly or indirectly, 25 State agencies and governmental bodies. It has become increasingly apparent that such varied interests must be coordinated on a state-wide basis to fully establish Delaware's position within the Valley. We, therefore, immediately instituted the U.S. Corps of Engineers Procedural Plan of Survey, with slight modifications, to cope with our particular needs. In addition, the various State interests have been requested to supply the State Coordinator with copies of detailed information which is passed on to the various Federal agencies for Basin-wide evaluation.

"The State of Delaware is contributing a tremendous amount of time and effort, without benefit of supplementary funds, to expedite the completion of the Delaware Valley Water Resources Survey Report. There is no doubt that the Commonwealth of Pennsylvania, the State of New Jersey, and the State of New York are making similar contributions.

"By coordinating Delaware's multiple interests into a State Report, a major contribution will be made to expedite the completion of the overall Basin Survey."

b. Second meeting. The second meeting was held on August 15 and 16, 1957, at Lehigh University, Bethlehem, Pennsylvania. The following progress report statement was made:

"On May 27, 1957, a meeting was held in Dover, the Capital of Delaware, at the request of the Delaware Coordinating Committee and by order of the Governor, Hon. J. Caleb Boggs. All Stat artments and Commissions, County Agencies, Municipal Departments, and other groups having a specific interest in the present and future development of the economy, wildlife, industrial planning, municipal and county planning, and other phases connected with the use of usable water were requested to attend this meeting.

"The Delaware Coordinating Committee, in view of the limited personnel of many of the groups represented, prepared an 'Assignment Outline,'

applicable to Delaware, which, for all intents and purposes, covers the problems posed in the 'Data Book' of the Corps of Engineers. Over 100 problems are listed in the outline.

"Cooperation between interests is our policy. Specific problems are outlined and each group has been instructed to carry out any one of the following:

a. Submit a report independent of other agencies.

b. Act as chairman for several interest groups in submitting a joint report.

c. Submit a cooperative report to the Chairman Group.

"Our report will be based upon 19 independent reports, 24 chairman reports, and 50 cooperative reports. By these means we expect to obtain the sense of the groups, the same as the Quaker method of obtaining the sense of the meeting.

"We, in Delaware, with each succeeding day, grow more concerned with the future. We are perpetually aware, from various sources of information, that within 18 short years, namely, 1975, the population of Delaware will increase 42.8 percent. Similarly, Pennsylvania will increase 22.4 percent, New Jersey 33 percent, New York 28.3 percent, and Maryland 45.8 percent. Until the United States Government furnishes figures to the contrary, we must accept the above percentages.

"Delmarva Peninsula is bounded by the Chesapeake Bay, the Atlantic Ocean, and the Delaware River and Bay. For this reason, Delaware can not divorce its economy from the remainder of the peninsula in certain fields of endeavor, expecially commerce.

"New Castle County contains Wilmington, the largest city of the peninsula. Thru New Castle County flow the products of the peninsula. In addition, New Castle County is blessed with those natural physical factors which caused Wilmington and the surrounding vicinity in the past to grow industrially.

"Such growth will continue to grow sharply as it has in recent years. The pattern is firmly established. However, the amount of usable water may have a limiting effect, as our industrial area depends on ground and surface waters. Our surface water resources are influenced by the usages upstream, and failure to receive sufficient water to fulfill basic needs may well impair the economy of our State. The impact of this survey is by no means localized when we consider the years 2010, 2060, and beyond. We can not divorce New Castle County from the remainder of this State, which are Kent and Sussex Counties, agricultural in nature and similar to Salem and other counties of southern New Jersey. In contrast, New Jersey, New York, and Pennsylvania contain many counties which are highly industrialized. If one of these industrialized counties should become less productive, the effect upon the remainder of the State is not as critical as that in Delaware.

"Census figures show that the percent of growth of the Delaware Basin area from 1930 to 1955 grew less rapidly than the entire country, however, the Wilmington area grew faster than any metropolitan area in the Basin and the remainder of the United States.

"Both southern New Jersey and Delaware have a vital interest in the Delaware River, due to the usages inherent to the River and Bay.

"Activity within the reaches of the Delaware River and its tributaries beyond tidal range is vital to the economy of our State."

c. Third meeting. The third meeting was held in Wilmington, Delaware, on November 14 and 15, 1957. It had been requested that Delaware's presentation include the State's policy and pending legislation with respect to land acquisition for water development projects. The following statement was made:

"At the second meeting of the Delaware Basin Survey Coordinating Committee held on August 15 and 16, 1957, at Lehigh University, it was suggested that the States present papers on their respective state laws and policies governing the development of water resources. The presentation should include state policy and pending legislation with respect to water development projects. It was further suggested that the subjects of flood plain zoning and flood insurance be discussed or reviewed. For reasons of brevity, we decided that the entire subject matter referred to above be incorporated into a single summary.

"In order to discuss development of water resources, it was deemed appropriate that a brief resume of the existing Water Law in Delaware be made part of this presentation. The legal aspects involving water use in the State of Delaware were reviewed and set forth in a memorandum, dated March 1955, by our former Chief Deputy Attorney General Vincent A. Theisen. A second report, dated November 1955 (Bulletin No. 314), entitled 'Some Legal Aspects of Water Use in Delaware,' was prepared by Harold H. Ellis and R. O. Bausman, of the University of Delaware, in cooperation with the Production Economics Research Branch of the Agriculture Research Service, U.S. Department of Agriculture.

"Both the former Deputy Attorney General's memorandum and the bulletin present similar findings which were summarized as follows:

"'The riparian doctrine of water rights is apparently in effect in Delaware with respect to natural watercourses, while some version of the English rule, based on the concept of absolute ownership, possibly applies to the use of percolating ground waters. Rights to use water for farm irrigation and other consumptive purposes appear to be more secure with respect to waters in the ground than to waters in watercourses, particularly those in the smaller streams. But these and other questions are not very clearly answered either by the reported court decisions or by the Delaware statutes.

"'The original riparian doctrine, which may possibly still be in effect in Delaware, has a number of possible shortcomings. It provides owners of lands bordering on streams with rights to use the waters for

drinking water, household needs, and other similar purposes, but the taking of water for farm irrigation and other consumptive purposes may not be permissible if it noticeably, or at least substantially, lowers the water level. This modified doctrine of reasonable use is now adhered to in several states. In general, this doctrine allows the water to be used for irrigation and other consumptive purposes so long as such use is found to be reasonable under all the circumstances. It appears to have fewer drawbacks and has the advantage of greater flexibility.

"'The Delaware water-right laws need clarification and possibly also modification. But in view of the complexity of the problems and the several alternative solutions that have been tried in other states, thorough study and discussion of various phases and possible solutions of such problems are advisable before any new legislation is adopted.

"'Some of the overall goals might be to adopt, modify, or continue such laws and other measures as will promote the beneficial, efficient, and safe use, and conservation, of the available water supplies, and help to develop any additional water supplies that may be needed in different areas. In part, the problem may revolve around the question of how to provide sufficient security in water rights to encourage desirable investments, while also providing a legally sound, practicable, and reasonably equitable water-rights system and a sufficiently flexible system to keep abreast of changing conditions.'

"On December 15, 1954, his Excellency J. Caleb Boggs, Governor of the State of Delaware, created a Water Resources Committee.

"The purpose of this committee was to review the water resources use and conservation problems within the State of Delaware, and to make recommendations to the Governor and the General Assembly as to what action, if any, might be necessary and desirable in the public interest. The findings of this committee were forwarded to the Governor on May 2, 1956.

"Based on this report, Senate Bill 98 was submitted to the General Assembly of the State of Delaware during its 1956 session to create a Water Resources Commission, setting forth its powers and duties. This bill was passed by the Senate on June 6, 1956. It was reported favorably on June 24, 1956, by the House Agriculture Committee; however, no House vote was taken on the bill. The future of this legislation is still in doubt. If this bill were to pass, the resultant Water Resources Commission would be able to control the taking of water or the diversion thereof from the various state waters, both ground and surface. In essence, this would create a modification of the riparian doctrine to one of reasonable use.

"With respect to land acquisition for water development projects, several State interests are able to obtain land for their specific need; namely, the Highway Department, the Game and Fish Commission, New Castle County Levy Court, and the City of Wilmington.

"In the past the Legislature has directed the State Highway Department to obtain land for dam sites, which included the purchase and condemnation of lands. Land for dikes may be obtained by this procedure. In order to provide for the free passage of water for draining of any road or

causeway under its jurisdiction, the Highway Department may enter upon lands contiguous or adjacent to such road or causeway in order to maintain or repair any existing artificial or natural ditch, drain, cover, or sewer. Further, it is empowered to keep water of ditches, drains, streams, and creeks within their proper channels, thereby preventing them from encroaching upon or flooding any road or causeway under its jurisdiction. The Department or its Agents may also enter upon and occupy the beds of any ditches, drains, streams, and creeks contiguous or adjacent to such roads or causeways and perform such work of construction, improvement and maintenance as may be necessary or desirable to prevent such encroachment or flooding.

"The Delaware Game and Fish Commission can purchase lands for use of wildlife, and these purchases could include areas needed for water development projects in accordance with the Game and Fish Commission needs.

"Our New Castle County Levy Court can purchase property; however, it is doubtful that it could purchase property for large reservoirs. The Levy Court has the power to condemn lands for storm drainage right-of-way.

"The City of Wilmington can proceed under an Act empowering the Mayor and Council of Wilmington to acquire water rights by purchase or condemnation proceedings. This Act states, 'The Board of Water Commissioners shall have the power to acquire, by purchase or condemnation as hereinafter provided, such water rights in the waters of the rivers or streams in New Castle County as may be necessary for furnishing to the City of Wilmington a supply of pure and wholesome water adequate to meet the present and probable future needs of the said City, and to appropriate for such purposes so much of the waters of such rivers or streams as shall be required therefor.'

"The rapidly increasing change in land use from agriculture to industrial sites and suburban communities, especially in the northern area of Delaware which lies in the foothills of the Piedmont Plateau, has resulted in the occupation of flood plain areas. The occupation of these lands has resulted in flood problems due to the absence of protective measures. With the continued rapid increase of population in this region the flood damage potential increases. Our present troubles of flood damage are mainly concerned with small tributaries. In order to cope with this problem, Governor J. Caleb Boggs signed into law Senate Bill No. 200 on June 28, 1957, which is an Act authorizing the State Highway Department to study and construct flood control measures along Little Mill Creek in Christiana Hundred and appropriating funds therefor. This Act appropriates $100,000 to the State Highway Department to approach the flooding problems in a logical and comprehensive manner. The study of the watershed of an entire stream, such as Little Mill Creek, should develop a better knowledge of the best way to minimize the flood damage.

"In a recent hydrological study conducted at the University of Delaware under the sponsorship of the State Highway Department, the inadequacy of data presently available on the subject of small drainage basins was clearly illustrated and emphasized the urgent need for more reliable design criteria.

"Our New Castle Regional Planning Commission is directed by legislative enactment to safeguard the well-being of the County, which

includes drainage as well as other improvements. Subdivisions now being constructed must be approved by the Commission. The Delaware State Highway Department is responsible for the drainage of the streets and requires that all streets be constructed above the flood water elevations. The New Castle County Regional Planning Commission, in consultation with the Highway Department, establishes the expected flood elevations. The need for sound hydrological data is most important. In a new subdivision, channel lines are chosen based on storm frequency runoff, and no construction is permitted in these areas known as 'Public Open Spaces.' This procedure has been reasonably successful. This approach, however, does not relieve the flood situation entirely, simply because an increase in building compounds the problems in earlier improperly developed areas and in the lower undeveloped flood plain regions.

"The Levy Court of New Castle County has prepared a bill for Legislature which specifies that they may obtain monies which would allow the Levy Court to clean existing streams and creeks to expedite the flow of water. The Levy Court is now asking for the power to establish a Storm Damage Board and, in addition, obtain the 'acquisitions of easements of a width not greater than two feet wider than the existing top of the bank.' However, wider easements may be acquired if necessary under specific conditions.

"In the coastal areas flooding occurs mainly within the tidal regions during intense storms and with the occasional hurricane. This coastal region presents different problems of flooding. Water movement is not as rapid as in the Piedmont Region during periods of increased runoff. The Delaware River and Bay are essentially drowned river valleys, and the adjacent flood plains are comparatively wide, consisting of tidal marshes covering large areas. Ensuing damages in these areas are usually due to excessively high tides. Difficulties, such as bridge destruction, also have been encountered in the past due to a sudden drop in water level on the downstream side of bridges with a resulting increase in pressure of the back waters. In many locations dikes have been constructed to protect the lowlands from the river and bay waters.

"The draining of marshlands continues in the State of Delaware. Tax ditch corporations are organized to accomplish this work.

"An additional factor, which may require considerable attention, is the continued report that there has been an increase in the level of the ocean. Some predictions have indicated that a rise of 1.5 feet will occur in the next hundred years. Such a change will have considerable bearing on problems in Delaware as well as in the State of New Jersey.

"The control of storm water must be considered of public interest and with the expected expansion in population and development in Delaware within the next 50 or 100 years, flood plain zoning on a statewide basis is vitally needed."

d. Fourth meeting. A general statement was made at the fourth meeting, which was held in the Edison Building Auditorium, Philadelphia, Pennsylvania, on February 27 and 28, 1958. The statement was as follows:

"At the request of Governor Boggs a meeting was held in Dover on January 31 of all the State and County Agencies connected with the State

Report for the Delaware River Basin Water Resources Survey. Twenty-three agencies presented interim progress reports at that time.

"Governor Boggs is keenly interested in this survey, and his remarks at this meeting clearly emphasized the importance of the water problem with respect to the future of Delaware. The Governor emphatically stressed the need for each agency to give its full support in providing information and supplementary reports for the use of the State Coordinators. It was further emphasized that every possible effort be made to continually improve and update information until the final draft of the State Report is completed. By this procedure a maximum amount of time would be provided for obtaining valuable detail. It is highly probable that where pertinent information was not readily available at the onset of this survey it could be compiled through these later efforts.

"In our task of preparing an intrastate water resources report, we are confronted with various problems and facts which may or may not be of interest to our neighboring States and Federal Agencies.

"In view of our marked increase in growth and development, during the past decade, it had become apparent a critical analysis of existing data was necessary. In this effort we have found that updating information has proven to be most enlightening. For example, we are now endeavoring to clarify the nonconsumptive use of water for irrigation purposes. Our most recent sources of information indicate that the use of water for this purpose is considerably greater than all previous estimates. A tremendous increase had taken place as recently as 1957. It is ironic how often an individual interest is completely unaware of another's use or water needs, and remains under the assumption that there exists no future problems of availability in his particular field of interest.

"We have continually maintained that men with long experience who have noted the changes within their sphere of activity could contribute materially to the projection of future development and progress within their respective areas. This basic wealth of experience must be heavily drawn upon if a complete or full evaluation with respect to projected growth and development is to be achieved. Local government or interest has always been the foundation of any constructive program.

"It would indeed be a serious oversight to place too much effort toward completing the report quickly and to expend comparatively little effort toward updating or striving to obtain pertinent detail. It follows that constructive criticism or review of all reports should be done most conscientiously, for in this way only can we expect a good report. Sufficient time should be provided for work of this nature.

"Another integral part to the updating of information is the influence which the comparatively recent interstate highway systems will have upon growth and development. It should be noted that the influence of these proposed arterial and defense highways must be considered a major generator of development; however, present projections, based on existing 1956 data and prior thereto, exclude this important generator of recent and future activity. We hope that serious consideration will be given, in the immediate future, to update information, specifically as indicated above.

"We are fully cognizant of the fact that Delaware is the most vulnerable of all our neighbors with respect to future water supply. Not only are our surface sources limited, but some untapped ground water aquifers have shown evidence of salinity intrusion at comparatively shallow depths. In addition, partially completed updating of inventory of present and future uses already indicate a need far beyond our initial expectations. It has become increasingly evident, if Delaware is in any way a parameter of the needs of our neighbors, closer scrutiny of the Delaware River's potential must be made; consequently, our request for a preliminary evaluation of a downstream structure. Certainly we are aware that such an undertaking would bring up staggering problems. To name a few: Existing municipal and industrial establishments could be in jeopardy; waste discharged in its present degree of treatment downstream from such a structure might in itself seriously affect multimillion-dollar interests in the lower Delaware River. In spite of these and probably many additionaly disadvantages, it still appears justified to seriously consider the feasibility of a downstream structure to attain the major advantage of sufficient water."

e. Fifth meeting. No formal statement was prepared for the fifth meeting, which was held in Honesdale, Pennsylvania, on June 26 and 27, 1958.

f. Sixth meeting. The sixth Coordinating Committee meeting was held at Hunter College, New York, N.Y., on September 18 and 19, 1958. The Corps of Engineers had requested each state to submit by September 1, 1958, a statement to cover the following request:

"That the State members furnish me (Col. Powers, District Engineer) and the other members of the committee, by September 1, 1958, their then current estimates of projected water demands and an indication of their projected plans for meeting those demands. To the extent that readily available information will permit, the estimates of demands should be indicated by general location, quantity, uses and time, realizing, of course, that the estimates will be subject to refinements and revision as the States and their subdivisions proceed with their own works in water resource development."

The following statement was prepared accordingly and was also read at the Committee meeting.

"We are submitting, herewith, present water use and projected water needs for the State of Delaware, by county, as requested in your memorandum of 11 July. The State of Delaware has been actively engaged in preparing an intrastate report as an appendix to your Valley report in which one of our objectives was the preparation of projected water needs. In order to reply to your memorandum, we have made every effort to expedite our time table in this regard and provide you with the requested information. Due to our size we have been able to collect, in the time specified, detailed data rather completely for projection purposes with respect to anticipated growth and water needs on a State level. Our projections are based upon many factors, however, we have intentionally employed what we consider conservative rates, until more finite evaluations could be made.

"We wish to acknowledge the participation and coordination from the following sources:

"1. Department of Agriculture, University of Delaware, with respect to irrigation.

"2. Department of Civil Engineering, University of Delaware, for surface water evaluations.

"3. Delaware Geological Survey, University of Delaware, for its ground water evaluation.

"4. State Board of Health, for its municipal water tabulations.

"5. The Highway Department, State of Delaware, and many other participants for its projected land use estimates.

"6. The Water Pollution Commission, for its ground water quality evaluation and industrial water inventory.

"7. The Highway Department and the statistician of the State Board of Health, for population, etc. projections for each county.

"8. Various major industrial groups for their invaluable assistance with respect to projected industrial needs.

"The following clarifying points are pertinent to the tabulation of Present Use and Projected Needs presented below.

"1. Present Use tabulations were compiled from the following:

(a) A complete inventory of industrial water use.
(b) A complete inventory of all irrigation use.
(c) A complete inventory of municipal water use.

"2. All industrial cooling waters and steam generation sources, from surface streams, are not included in the Present Use totals. A major portion of these waters are brackish, however, approximately 15% is taken from fresh water streams. Projected Water Needs, therefore, do not include the needs for industrial cooling or steam generation.

"3. An estimate of the land availability had to be resolved before irrigation projections could be made. The projected irrigation needs shown is approximately 15% less than much of the current thinking. However, until more finite evaluations could be made, this conservative figure had been used.

"4. For the purpose of water supply and good water works practice, the 30-day Maximum Use was applied throughout, except where noted.

"5. Present domestic consumption (30-day Maximum) in Delaware averages 100 gcpd. Until further study a conservative 125 gcpd was used for the year 2010 and 150 gcpd for the year 2060. Present thinking and past records clearly show domestic water requirements have increased at a much more rapid rate.

"6. Due to time limitations, means of obtaining Projected Needs with respect to industrial water had to be modified. Our largest industrial water users were given detailed consideration with respect to Projected Needs. A conservative average of 5% increase per year was applied to the remaining industries.

"7. Water use with respect to irrigation is projected on a 60-day maximum basis, since this is the potential period during which water will be applied. If expressed as 30-day maximum, the figures would be greater.

"Summary Water Use and Projected Needs excluding industrial cooling and steam generation, in the State of Delaware, is presented in Table I.

TABLE I

STATE OF DELAWARE SUMMARY
WATER USE & PROJECTED NEEDS
EXCLUDING INDUSTRIAL COOLING & STEAM GENERATION * MGD

(30-Day Maximum)

	NEW CASTLE			KENT			SUSSEX		
	1958	2010	2060	1958	2010	2060	1958	2010	2060
Industrial	71.0	319.9	1262	23.35	81.85	286.35	31.45	112.4	436.3
Municipal	40.1	114.0	337.5	7.63	34.30	92.40	6.34	29.95	73
Irrigation	24.65	** 153.5	0	53.80	** 216.50	** 715.0	25.35	** 331.0	** 1285
TOTAL	135.75	587	1600	84.78	332	1094	63.14	473	1794

* = Taken from Surface Streams.
** = 60-Day Maximum.

"We have endeavored to project the needs for the year 2060 simply because we are cognizant that this period is quite pertinent to the overall problem.

"In your memorandum of 11 July, you had also requested that consideration be given of the water sources needed to meet the projections. Surface water sources lie in the extreme upper portion of the State of Delaware and in contrast our major ground water sources are located in the extreme southern portion of the State of Delaware. The following are pertinent to surface and ground water availability:

"1. <u>Surface Sources</u>

"Detailed analysis of the dam sites, proposed by the Corps of Engineers, located on the Brandywine, White Clay and Christina water sheds, have been carefully evaluated. At the pool elevations noted, the combined (Brandywine, Christina, White Clay) minimum range of development would provide a safe yield for a 25-year recurrence interval of 272 mgd. Similarly, the combined maximum range of development would provide a safe yield for a 25-year recurrence interval of 402 mgd. However, several considerations must be resolved before any estimate could be made of what portion of these sources could be considered "safe yield" for the State of Delaware. These considerations involve one or more of the following:

"(a) Approximately 90% of the Brandywine pool would of necessity be in Pennsylvania. Diversions for out of basin use are highly probable and consequently the safe yield would conceivably be reduced.

"(b) Irrigation trends and experience, if practiced to any reasonable extent, indicate that this safe yield could be materially affected.

"(c) The proposed Brandywine dam site involves approximately 85% control of its waters. This should be compared to the very extensive water development of Gunpowder Creek by the City of Baltimore, constituting 56% control. It is possible such extensive development may not be feasible.

"If we could be so bold as to assume that the entire minimum development of 272 mgd, referred to above, could be assured for the State of Delaware, we would have less than half the water required for New Castle County alone in the year 2010, and considerably less for the year 2060. The ground water sources in New Castle County are comparatively minor.

"2. <u>Ground Water</u>

"Ground water safe yield in the State of Delaware has been estimated at 418 mgd. Of this total 400 mgd or 95% lies in the Pleistocene sands. These Pleistocene sands are located in Sussex County and the southern half of Kent County. Our projected needs for Kent and Sussex Counties total 800 mgd in the year 2010, whereas, our ground water availability indicates half of this amount. The picture beyond 2010 is obviously even more critical.

"A few pertinent considerations appear appropriate in conjunction with the ground water availability estimates, namely:

"(a) Ability of ground water recharge is not too well known and complex. Recharge could be greater than the estimates now used, however, the reverse is equally true.

"(b) We have experienced evidence of saline intrusion in our lower counties, in fact, we have found high chlorides in untapped aquifers.

"(c) Ground water quality dictates treatment before universal use could be made. Extensive analyses indicate that waters from the Pl tocene sands are invariably very acid (low pH) and extremely high in iron.

"Our projected needs, therefore, for the year 2010, excluding industrial cooling and steam generation requirements, total approximately 1,400 mgd. If all surface and ground water, as indicated above, were readily available for the State of Delaware we would still receive less than half of our requirements for the year 2010. The only other source of water available to the State of Delaware is the Delaware River.

"We wish to reiterate that the above projections are "considered" estimates, however, we feel they are conservative for the various reasons outlined. More finite evaluations, in the future, of basic projection rates may result in greater estimates."

g. Seventh meeting. The seventh Coordinating Committee meeting was held at the Academy of Natural Sciences, Philadelphia, Pennsylvania, on January 22 and 23, 1959. The Corps of Engineers had requested brief statements be made on the policies governing the compatible use of multiple purpose reservoirs. The following summary type statement was presented:

"In the momorandum dated 17 November 1958, from Colonel Powers, Chairman of the Delaware River Basin Survey Coordinating Committee, it was requested that a brief statement on the policies governing the compatible use of multi-purpose reservoirs and flowing waters be made by each State. In accordance with the above request various agencies in the State of Delaware were approached to provide a statement of their policy or thinking in regard to multiple-purpose use. The following comments constitute abstracts and/or condensations of each of the replies received.

"'Policy is covered in the enabling acts authorizing the acquisition and installation of an improvement. Legal interpretation holds that unless multiple use of an installation is specifically authorized in the authorization act or charter, it is specifically denied. If authorized, but not clearly defined, the administrators of the fee have the determining responsibility regardless of whether wholly public, wholly private or a combination thereof of these precepts hold.'

"The consensus of the Health and the Water Works interests stipulates that the American Water Works Association policy on recreational use of reservoirs should be followed. This policy is outlined in the Water Works Engineering, March 1958 issue. In brief, reservoirs are classified as Equalizing Reservoirs, Terminal Reservoirs, and Upstream Reservoirs. As a matter of classification, Equalizing Reservoirs are those 'within the area served, delivering finished (water ready for consumption) to the distribution system.' Terminal Reservoirs are classified as 'areas providing end storage of water prior to treatment.' Upstream Reservoirs are those 'providing storage of untreated water at various points in the watershed to provide or supplement the supply at the terminal.' This Board considers generally that 'recreational use of Equalizing and Terminal Reservoirs and the adjacent marginal lands is inimical to the basic function of furnishing a safe and palatable water supply to the system's customers and should be prohibited.

"The Boards policies for Upstream Reservoirs has some leeway with regards to other uses but depends upon the category of the quality of the water prior to delivery to Terminal Reservoirs. Class A: where the water impounded is 'clear and clean enough to be distributed to the customers after disinfection only' safe practice 'requires the prohibition of all recreational activities on the water and watersheds land in and about such storage reservoirs.' Class B: where the water 'impounded from an area not heavily inhabited, is allowed to flow from storage in a natural stream to the point of withdrawal, and required treatment (in varying degree) in addition to disinfection' ... 'limited recreational activities on such reservoirs and adjacent lands are considered permissible under appropriate sanitary regulations.' Class C: constitutes impounded water which has flowed in a natural stream prior to impoundment and has received polluting material prior to its storage. Such water having been confined until low stream flows necessitates its use, with complete treatment, recreation is considered permissible under appropriate sanitary regulations.

"For domestic use 'control of water supply reservoirs must remain the prerogative of the water purveyor.'

"'Generally, from a water works standpoint, there should be no jeopardizing of the quality and quantity of the raw water supply. Also the reservoirs should be considered as classified by the American Water Works Association.' Further, quantity should not be placed in jeopardy so that a multiple use interest could prevent Water Departments from lowering the levels for use when the water need arises.

"The Delaware State Development group briefly state that they concur with multiple use of reservoirs and streams for purposes of industry and recreation and game fishing.

"Our New Castle County Levy Court representatives expanded their thinking with respect to compatible uses of multiple purpose reservoirs and flowing streams. It is their consensus 'that the priority in policy making with respect to multi-purpose reservoirs should be as follows:

"1. Water Supply.
"2. Flood Control.
"3. Irrigation and Power.
"4. Recreation and other uses.

"The range in relative importance of each possible use is such that only the most general statements of policy are possible without the consideration of individual conditions. They 'classify water supply reservoir uses into three classes:

"'1. Those to control low river flow and not directly connected to water systems.
"'2. Raw water storage directly connected to water supply.
"'3. Treated water storage.'

"The first use is considered 'compatible with flood control, irrigation, power and recreational uses.' However, 'the controlling

authority of such facilities depends on the relative importance of water supply' and they 'feel that the second use may be compatible with flood control, irrigation, and power, but not with recreational uses except under rigid control.' They further state 'that the controlling authority of such facilities should be the water supply authority.' The third use, namely, treated water storage, is considered 'incompatible with any other use and must be controlled by the water supply authority.' The County finally stated 'that in the case where water supply is not in question the other uses are generally compatible, but that the control should be in the authority with the higher priority.'

"Our Fish and Wildlife group reports that 'adequate plans should incorporate public recreation on large municipal water supplies.' No further clarification was made of this statement to specify whether reference was being made to Equalizing, Terminal, or Upstream Reservoir type impoundments. They further stated that 'presently planned and future main-stream impoundments on the Delaware River should protect the fishing industry, both sport and commercial, by means of assuring adequate facilities for migrating fishes.' 'In addition, plans for management of the fisheries created in the impounded waters and in waters below the dams should be incorporated in the preliminary financial aspects of any development.'

"It would not be good judgement to consider procurement of water and/or its initial potential multiple use as a complete entity without including the problems of used water quality. Inability to dispose of used water, economically, has proven, on occasion, the deterrent of utilizing an available water supply. As population and development increase there exists little doubt that the disposal of used water will become a more and more significant part or deterrent to water resources development.

"The pollution abatement program in Delaware is so organized and operated as to include the thinking as represented by the Health Department, Fish and Wildlife, Shellfish, Highway, Water Supply, County Government and Industrial representation. The best water usage approach for all state waters is basic to the success of the Program.

"'Pollution affects each and every water use, and consequently its influence is fundamental to the future of each interest. Present water quality varies from polluted areas to conditions where little or no pollution exists. Obviously we cannot survive or remain prosperous if we permit detrimental pollution to continue. Neither can we prosper if we demand the complete removal, without exception, of all contamination reaching State waters.' 'It is inevitable that a compromise or, more appropriately stated, an equitable solution be sought.'

"'A limit to the degree of contamination, which can be accepted within reason, must be prescribed within the realm of best water usage. Domestic raw water supply requirements can vary from demanding no contamination (no use of upstream water) to the contamination of such water as long as the ability to supply a safe and palatable water is not endangered or impaired. In a multipurpose stream, complete treatment for domestic water supply is unavoidable. Pursuing this line of reasoning, the various water users affecting the water quality of a stream must pattern the treatment of their discharges so that the primary use is not endangered.'

"'There is little doubt that economics are a major factor in all waste treatment. Whether it be a municipality or an individual industry, each will search for the most economical means of handling its problem, taking into consideration the self-purification ability of the receiving body of water between the discharge and the other water users. Excessive waste treatment requirements may prevent industrial growth or make its position untenable.'

"'The question of equity becomes even more difficult as we delve into water uses. For example, decisions with respect to domestic water supply are less complicated simply because the intake is at a specific location and the sources of pollution are at designated distances from the intake. When we consider such usages as recreation, parks, boating or fishing, fish, wildlife, and shellfish, the principle of employing or utilizing the self-purification capacity of the stream becomes more complex. Streams, ponds, lakes, estuaries, and bays are fundamental to the above water usages. Further, such interests or needs for recreation facilities are progressively more valuable the closer they are located to the population centers. As we move closer to the sources of waste discharges, however well treated, we are progressively decreasing the available self-purification capacity of the particular body of water in question. Parks and playgrounds have greater flexibility of location and can, under certain circumstances, be so placed as not to conflict with the full use of a stream's self-purification action. Such usages as natural oyster beds and marsh areas are fixed and cannot be moved. To protect these latter usages, the zone of influence from municipal and industrial waste discharges must be carefully ascertained. A buffer zone between these latter usages and sources of waste discharge becomes a basic necessity. To avoid complete destruction of such usages as natural shellfish and marsh areas, limiting domestic and industrial development in certain localities becomes unavoidable.'

"'In an effort to be realistic, one must conclude that it is inevitable that we will have increases of population and to support this increase in population we must have industrial development. In existing areas of moderate to heavy population and industry density, it is only reasonable or equitable to conclude that the self-purification action of a stream must be considered as an integral part of pollution abatement. Further, to provide for the inevitable population growth and industrial development, it appears both reasonable and equitable to assume that areas involving comparatively minor facilities or assets for fishing, recreation, boating, parks, etc., will give way to various degrees of urbanization and industrialization. All major recreational usages, however, must be fully protected. The need for such assets is also an integral part of our way of life. It is conceivable that we will eventually reach a point of saturation whereby further advancement in growth and development must be limited or we will destroy that which we strive to preserve at the present time. When that time comes, other undeveloped areas of this Nation will experience rapid growth and development. We must not be placed in a position whereby we are saturated with population and industry without the recreation facilities needed for full enjoyment of life itself.'"

h. Eighth meeting. For the eighth meeting the Chairman of the Committee requested a report of the policies with regard to using low flow

augmentation in lieu of a degree of sewage treatment higher than primary level. At this meeting, held at Split Rock Lodge, Lake Harmony, Pennsylvania, on May 13 and 14, 1959, the following report was presented:

"The State of Delaware has conducted water quality (pollutional) investigations in the Delaware River since 1952. Considerable time, effort and money have been expended in the last three years to study not only the prototype but also the Delaware River Model at the Waterways Experiment Station, Vicksburg, Mississippi. Much of the prototype study work in this three-year period has been conducted jointly with Incodel and the City of Philadelphia. The Delaware River model work is specifically a joint experimental investigation in cooperation with Incodel, Pennsylvania, New Jersey, and the City of Philadelphia. The conclusions and comments in this section, or drawn from the intensive investigative phases, are those of Delaware. A detailed formal report will be prepared jointly with Incodel and our neighbors in the near future.

"When dealing with an estuary one cannot emphasize too strongly that such a body of water has certain inherent complexities which are not present in streams unaffected by tidal action. Due to the nature of water movement in an estuary, certain conditions are created in regard to pollution buildup and recovery which need special considerations.

"The generally accepted concept that increased flow improves water quality is open to serious question when considering pollutional aspects in estuarine waters. Recent findings establish the fact that the effect of increased flow is not the same in all portions of the tidal area. Further, it is no longer a matter of degree of improvement, but rather whether it is beneficial or nonbeneficial. Unfortunately, the State of Delaware will be subjected to decreased water quality during specific periods of increased flow.

"The entire problem, however, cannot be so simply resolved. Increasing the river flow progressively reduces the water quality in Delaware until flow stages of approximately 4,500 to 5,000 cfs (measured at Trenton) are exceeded. Thereafter, true dilution begins to emphasize its presence, and water quality begins to improve with further increases of flow. However, the water quality in Delaware does not return to its original dry-weather level even with flows exceeding 7,000 cfs. Control of flow may conceivably aggravate the problem if regulated at too low a flow stage.

"Another not-too-often-discussed phenomenon altered by control of natural flow is scour. It appears logical that Mother Nature has provided a wide range of river flow with the expressed purpose of providing a wide range of scour needed to flush all degrees of sedimentation from its rivers and estuaries. There is little doubt that the removal of peak flows will result in a decrease of scour. Further, peak flows just able to produce scour upstream will be only partially effective downstream since velocities of flow are sharply curtailed accordingly. Consequently, controlled river flow will reduce scour disproportionately, in that upstream areas may be slightly affected; however, the lower reach may suffer considerably. At the comparatively lower stages of controlled flow, undesirable sedimentation may still be scoured from upstream areas into Delaware, whereas the needed peak flow to scour or further carry upstream sediment through this lower reach may become nonexistent.

"The entire problem may be resolved down to a matter of balance. Certainly one cannot help but recognize such potential benefits of flood control, water supply, and recreation upstream through regulated flow practices. One may also recognize similar benefits made available to downstream areas. However, improper regulation could create a non-beneficial effect to the lower reach of the estuary, specifically through decreased water quality, while still being beneficial upstream.

"It is obvious that the needs for growth and development and their byproduct, waste are responsible for the dilemma we face. Naturally, these phases will continue to increase, and our problems will become even more critical. Presently, the Delaware estuary receives a load (population and industry) equivalent to approximately 4,200,000 persons after treatment. Of this total, Delaware claims the equivalent of slightly under 600,000 persons. It should be emphasized that this 4,200,000 load is after treatment, and the accepted degree of treatment was established indirectly by the ability of the Delaware River to consume the load without ill effect. Naturally, the potential total untreated load would be considerably greater, probably in excess of 10,500,000 equivalents.

"Sedimentation of pollutional material in the Delaware estuary should be at a minimum, since settleable solids discharges are not permitted and this requirement is completely complied with, for all practical considerations. Sedimentation will continue, however, due to soil erosion and interaction of colloidal and dissolved wastes with each other and/or salt water. These latter type discharges reaching the Delaware, after treatment, constitute the more difficult and costly portion of the waste to remove if and when the need arises.

"Presently it is estimated that approximately 60 percent of the total waste load tributary to the Delaware River is removed by existing waste treatment facilities. This 60 percent represents the average removal resulting from the existing primary and secondary units.

"The primary degree of treatment (35% removal) is required of wastes tributary to the Delaware River from the State of Delaware. Complete treatment of a municipal wast containing a moderate amount of industry can be expected to remove 90 percent of the total load. Industrial wastes alone are not, as a rule, amenable to such a high degree of treatment simply because either technology is lacking or costs for a high degree of treatment become prohibitive. Since theindustrial and domestic loadings in the Valley are essentially equal, the maximum degree of treatment may eventually reach an estimated 80 percent reduction of the total potential load.

"With a total load in the Valley of approximately 1,750,000 pounds of B.O.D. per day the existing 60 percent reduction results in 700,000 pounds reaching the Delaware River daily. It has been estimated by the OBE that the average increase of population and industrial development in the basin will be 250 percent greater by the year 2010. Assuming the increase to take place uniformly, 100 percent increase can be expected by 1980. This would mean a pollutional loading of 3,500,000 pounds of B.O.D. per day, or double the present discharge. At the contemplated maximum 80 percent reduction, a discharge of 700,000 pounds in

the year 1980 would occur, which is equal to the present discharge. Therefore, long before 2010 conditions would become untenable in that the estuary would become an open sewer.

"A fundamental part of the problem revolves about the present quality within the estuary and whether it is considered satisfactory for the best water usages. It has been pointed out previously that the State of Delaware will not require additional treatment at present since under normal conditions the water quality is satisfactory. However, following periods of increased flow during the summer and early fall seasons, Delaware experiences undesirable quality due to scour and partly due to the shift of the pollution sag from upstream downstream.

"Therefore, with the advent of stream regulation, the State of Delaware can expect lesser quality if the controlled flow is maintained at too low a stage during the summer and early fall, and a decrease in the scour of sediments. Lack of early consideration of treatment needs may require an outlay of funds for secondary treatment, compounded with cost of operation, exceeding $15,000,000 long before present projections. Unless other concrete benefits from low flow augmentation can be shown for the State of Delaware, there exists considerable doubt of the good such an undertaking would achieve.

"It appears evident from the above discussions that if secondary treatment of all wastes is completed, we shall, by the year 1980, be confronted with the artificial and natural recovery capacity limit for treated wastes tributary to the Delaware River. Due to practical and financial problems involved, it appears realistic to assume this limit may be reached even before the year 1980 since much must be done now to meet this minimum need. Being confronted with this critical period revives certain statements made by various participants at the Barrier Hearing held in Wilmington on October 20, 1958. Much stress was placed, by our neighbors, on the aggravation of the pollution problems if a salt water barrier should become a reality. We reiterate our previous statement that the gravity of the waste removal phase is ever present in the not-too-distant future whether a barrier is constructed or not. The solution of the overall waste problem must, of necessity, take a new approach. The innovation could conceivably adopt the approach of segregating the more difficult wastes to treat and convey them through trunk sewers to the ocean. This procedure is essentially the procedure suggested in the San Francisco Barrier Study. Now is the time to resolve the waste disposal problems of the near future, not 1980 or thereafter."

SECTION IX

PUBLIC ARCHIVES COMMISSION
CONSERVATION OF CULTURAL RESOURCES

9.01 INTRODUCTION

The Delaware River Basin has one of the richest historical backgrounds of any section of the country. This pertains not only to the colonial and Revolutionary periods but from prehistoric times to the twentieth century. During the years of occupation by the Indians and immediately after the arrival of the first settlers the Delaware River and its tributaries provided practically the only means of travel. Consequently, the earliest settlements were made at places close to the water in order to facilitate travel. The Indians also selected camp sites and hunting areas close to the Delaware River and the many streams feeding it. The abundance of Indian placenames throughout the Delaware River Basin gives ample testimony to this, as do also the quantities of Indian artifacts found on the surface or unearthed by archaeologists throughout the area.

The first permanent white settlement in the Delaware River Valley was made at Fort Christina, now Wilmington, in 1638. There were subsequent Swedish settlements across the river in New Jersey and farther up the river at what is now Chester, Tinicum, and Philadelphia. The purpose of these Swedish settlements was to obtain from the Indians beaver skins and other furs to be sent to the mother country in return for the many supplies needed by the colonists in this New World settlement. In time these settlers met competition from the Dutch, who had also settled on the South, or Delaware, River at an early date and who had established a small colony as early as 1651 at what is now New Castle. Disagreements over trading interests resulted in armed conflict, with the result that in 1655 the Swedish settlements on the Delaware were conquered by the Dutch under Peter Stuyvesant and Swedish colonization in this part of the New World was brought to an end.

The Dutch were interested in establishing a colony as an outlet for their products and also to obtain their share of the resources of the New World. Great quantities of beaver pelts were obtained from the Indians and shipped back to the mother country. In turn the Dutch came in conflict with the English, with the result that in 1664 the Duke of York's expedition to the New World not only occupied New Amsterdam and renamed it New York, but another expedition was sent to the South River and the Dutch settlements there were seized also, then renamed and included under the rule of the Duke of York. This authority continued until 1682 when William Penn obtained, through deeds from the Duke of York, a title to the Delaware counties. He first landed in America at New Castle on October 27th of that year. Under the proprietary government of William Penn the Delaware counties flourished and the commerce of the Delaware River Valley also grew in volume. It consisted not only of the trading of products needed in the New World with England but there was also a coastwise trade with Maryland, Virginia, New York,

New England and even with the West Indies. In time the mainstay of this trade was flour, milled on the Brandywine, and large quantities of biscuit were made there for use on the southern and West Indian plantations. As early as 1729 no less than 4,500 immigrants landed at New Castle in one year. This gives some idea of the way in which the colonies along the Delaware were expanding. Even greater numbers were arriving at the Port of Philadelphia and moving into the back country to found new communities and settlements. All the while the River and its tributaries were the main source of travel. Communities were growing up along this readily accessible stream and they achieved more importance as the settlements grew. This process continued during the colonial period and up to the time of the Revolution in 1776. Immigration and commerce were seriously interrupted but these new American states of Delaware, Pennsylvania, and New Jersey were becoming self-sufficient now that they were separated from England. Industries had to improvise despite the interruption of the war. Shipbuilding flourished as never before and the whole concept of trade was changed. After the Revolution there was a great resurgence as the new American states attempted to build their own trade and commerce, as well as industries, for which they had previously depended upon in the Mother Country.

All the while new communities were growing up, greater volumes of trade and commerce with bigger ships were appearing in the Delaware River and its branches. Trade with the Orient was established and the West Indies trade was getting larger. This process continued through the years and the first interruption to it was the appearance of steamboats on the Delaware. John Fitch made his first trial excursion with a steamboat on the Delaware on May 1, 1787, and in October of the next year he began the first steamboat passenger service in the world between Philadelphia and Trenton. Gradually steamboats were replacing sailing ships and shipbuilding increased along the Delaware River to the extent that it was referred to as "The Clyde of America." Just as sails gave way to steam, so did wooden ships give way to iron, with the result that in 1843 we find that the "Bangor," the first iron ocean-going propellered steamship built in the United States, was constructed in the Wilmington yards of Harlan & Hollingsworth. During the years 1844 to 1887 this yard built 232 boats of all types. Other active shipyards in the State were Betts & Pusey, later Pusey and Jones, and also the Jackson and Sharp yards.

At the same time that it had been demonstrated that steam could propel boats the canal era and the turnpike era flourished. They were followed by steam locomotives which came into being in Delaware as early as 1832. These grew, expanded, and emerged with the result that steam packet boats from Philadelphia brought passengers to New Castle who then boarded trains of the New Castle and Frenchtown Railroad which took them across our State to the western terminus at Frenchtown at the headwaters of the Chesapeake Bay. From there passengers and merchandise went by packet to Baltimore and then to other destinations. This flow of traffic across the northern part of our State, which had expanded from colonial times, further increased with the years and larger railroads such as the Baltimore and Ohio and the Pennsylvania Railroad replaced, in time, the New Castle and Frenchtown, as well as the Delaware Railroad. It was then no longer necessary to depend only on the water routes. Inland travel was

increased with a result that many of the industries which had grown up along the water courses lost some of their importance. Sail lofts and rope walks diminished or disappeared and flour mills soon found that it was not necessary to be located only along water courses for the transportation of their product. This had the effect of opening new traffic routes in the State, new towns and communities came into being and some of the older ones lost part of their importance. Name changes occurred, and at the same time as the growth and expansion was taking place, there was in many communities a continuation of the stronger industries and commercial establishments dating from the early times.

Through this transition from dependence on water power alone into the era of steam and, more recently, electrical and diesel power, we see less dependence upon water for power and transportation. Meanwhile industrial uses and larger populations are requiring larger amounts of water than was heretofore necessary. It is for these reasons that this survey has been called for and the possibilities of water conservation are being examined. This is a natural resource that is most valuable to the life of our State and one which through conservation can be utilized properly.

9.02 CONSERVATION OF CULTURAL RESOURCES

The necessity of conserving natural resources has long been recognized and much progress has been made in this type of preservation. On the other hand, we have been slower in conserving many of our cultural resources. These resources range from the Indian artifacts of this area through all the arts and crafts of our forebears. Some of their thoughts and activities are preserved in manuscripts, printed books, and recorded history. Other early activities are revealed through surviving works of art or aspects of our local government which have been perpetuated for generations. For this study we shall confine ourselves to one aspect of our cultural heritage, namely, historic houses, buildings, and sites.

a. Historical sites in Wilmington and vicinity. In Delaware we are fortunate to still have in a fine state of preservation the early Holy Trinity (Old Swedes) Church built in 1698 by the Swedish congregation for the missionaries sent to minister to the descendants of the first colonists. Nearby in Fort Christina Park stands the noteworthy monument by Carl Milles, the famous Swedish-American sculptor. This great work of art was given by the people of Sweden to the people of the United States in 1938 to commemorate the colonization of New Sweden 300 years earlier. Included within the bounds of this park is the natural wharf of rocks where the settlers first landed. Fort Christina State Park is as important to the people of the Delaware River Basin as Plymouth Rock is to New England or Jamestown is to Virginia. It is a major tourist attraction which should be better known. Also in Wilmington is the Old Town Hall, built by Peter Bauduy in 1798, now the home of the Historical Society of Delaware. The early Bank of Delaware building which formerly stood at Sixth and Market Streets was moved to its present location to become the headquarters of the Delaware Medical Society and the early First Presbyterian Church was saved by the National Society of Colonial Dames of America in the State of Delaware and moved to the Park Drive for their headquarters. Nearby is the famous Henry Francis du Pont Winterthur Museum with its fabulous collections of American decorative arts. The Hagley

Museum, which was opened to the public on May 25, 1957, is located in the restored Henry Clay Keg Factory, one of the buildings in the group of the du Pont Powder Mills along the Brandywine. Here, in a series of exhibits, is being portrayed the industrial history of the United States, with particular attention to that of the Brandywine Valley.

b. Historical sites in New Castle. New Castle is one of those rare colonial cities which still has a number of its 18th century buildings still standing. Some years ago the people of New Castle had the vision to save the fine Amstel House, which has been restored and furnished with antiques of good choice, and opened as a museum. In the 1930's the Old Dutch House was also acquired and, after careful restoration and furnishing, it too has been opened as a museum. In more recent years the State established the New Castle Historic Buildings Commission for the purpose of restoring the Old Court House and acquiring adjacent buildings on The Green, namely, the Arsenal and the Academy. The Old Court House, which is one of the earliest in the country, and Delaware's colonial capitol, and its capitol immediately following statehood, is now undergoing restoration and will soon be opened to the public. The acquisition of the nearby buildings will assure their preservation and the proper protection of The Green in the center of the town. The citizens of New Castle have also shown their appreciation of the colonial architecture of their community by the manner in which they have maintained Old Immanuel Church and the recent excellent restoration of the Old Dutch Church by the Presbyterian congregation. In addition, individual citizens have taken pride in their historic homes, and, to name a few, the Read House, the McWilliams House, the Gunning Bedford House, the Van Luevenigh House, the Rosemont House, the Gemmel House, the Nicholas Van Dyke House, the Kensey Johns House, the Rodney House, the Penn House, and the K. J. Van Dyke House, all receiving careful attention from their owners.

Another progressive step for the conservation of cultural resources was begun in November 1946 when Colonel Daniel Moore Bates and Mrs. Francis B. Crowninshield began an architectural study of historic New Castle. The resulting report prepared by the architectural firms of Perry, Shaw & Hepburn of Boston, and George E. Pope & Albert Kruse of Wilmington, was presented to the New Castle Historical Society. As a result of this report a number of the citizens of New Castle sponsored, and were successful in having approved, historic zoning to protect the older areas and the houses and buildings within them. This farsightedness should indeed help preserve for posterity this rich cultural heritage which New Castle enjoys. For many years citizens of this town have sponsored A Day In Old New Castle, when many of the privately-owned homes are opened to the public. This has done much to further the cause of historic preservation in this community.

c. Historical sites in Odessa and vicinity. Odessa, formerly known as Cantwell's Bridge, is another example of a colonial town which still retains many of its fine early houses and buildings. Nearby Old Drawyers Church was begun in 1773 and remodeled in 1833. It is an excellent example of a Presbyterian meeting house of that period. Within the town of Odessa there are two particularly fine houses, the David Wilson House, which contains the Corbit Library and has the distinction of being the first free library in the State; and the William Corbit House, which

has in recent years been restored by Mr. H. Rodney Sharp, of Wilmington. These two houses and Old Drawyers Church were all built upon plans prepared by Rober May and Company, of London, England. The William Corbit House is one of the architectural gems of the State and it is tastefully furnished with antiques, most of which were obtained within a radius of 100 miles of Odessa. It is also noted for its magnificent gardens. Mr. Sharp has given leadership to the citizens of this community in the restoration of their homes and he has acquired other noteworthy houses which he has restored. Here, too, the people of Odessa, through the Community Center Association, frequently hold an Odessa Day when many of these houses and buildings are opened to the public. The Old Friends Meeting House of 1783, the Chief Justice Lore House, the Mailly House, the January House, the noted "Fairview" House, also built from plans by Robert May & Company, the William Polk House, and the Thomas House are notable among the ones to be seen on Odessa Day. The well-constructed houses of former years are still providing good living accommodations and the wide, tree-lined streets make Odessa a very attractive community and provide a marked contrast to some of the quickly-built developments of today.

d. Historical sites in Dover and vicinity. Dover, another of Delaware's towns of colonial origin, besides being the State capital and the Kent County seat, has a wealth of early houses and buildings. The Green, in the center of the town, was ordered laid out by William Penn in 1683 and at the east side of it is the Old State House built 1787-1792 on the site of an earlier court house of 1722. On all sides of The Green are 18th-century houses which are still lived in and enjoyed by their owners. Notable among them is the Ridgely House of 1728, the Reverend John Miller House of 1780, the Fisher-Comegys House of 1790, the Kent County Court House, and others. Near by is Old Christ Church, built 1734, as a mission of the Church of England. A short distance west of the Dover Green on "Meeting House Square," on land given by William Penn to the Presbyterians, is the Old Presbyterian Church, built 1790, on the site of an early log church. This restored building is now occupied by the Delaware State Museum. The State of Delaware also deserves much credit for erecting its buildings in the same style of Georgian architecture reflected in the old buildings of Dover. Notable among these are the Legislative Hall, the State Highway Department administration building, the Hall of Records, the Kent County Welfare Building, and the fine new Colonel John Haslet Armory of the Delaware Army National Guard. As in New Castle and Odessa, the citizens of Dover, through the Friends of Old Dover, have open-house days on the first Saturday and Sunday in May of each year. This organization meets throughout the year and is interested in furthering historic preservation and recapturing the colonial setting by landscaping through the planting of trees. This group has also sponsored historic zoning, which has been approved by the City Council, and should do much to preserve the cultural heritage of this community. Of the notable houses in this community are: "Woodburn," the substantial brick house on The Green built by Dr. James Sykes in 1812, the Thomas Stevenson House of about 1800, the James Bellach House of 1770 now the Episcopal Rectory, the Old Dover Academy, and nearby are "Great Geneva," "Eden Hill" Farm, and "Aspendale," at Kenton. The John Dickinson Mansion, near Dover, was given to the State by the National Society of Colonial Dames of America in the State of Delaware. Following restoration it has been furnished with antiques

obtained through gifts and purchases. The gardens are being developed in the same manner. This fine 1740 house is now open to the public as a historic house.

e. Historical sites in Lewes and vicinity. Lewes, another early Delaware town, with a colonial background and a long history as a maritime community, has its share of old houses and buildings. Notable among these are: Ryves Holt House, Colonel David Hall House, Chambers House, Fisher House, David Rowland House, and others. Tourists are attracted to St. Peter's Protestant Episcopal Church and its ancient cemetery; the Methodist Meeting House established 1791, the Presbyterian Church founded about 1707, the Zwaanendael Museum and the DeVries Monument. Here the restoration movement has not been as advanced as in other parts of the State, but it is indeed gratifying that in recent years the Daughters of the American Revolution have first engaged in research to determine the origin of these early houses and then designated them with a distinctive marker utilizing the coat-of-arms of Lewes, England. Then to interpret the meaning of these fine houses they prepared an excellent historical guide. These two actions of recent years on the part of this patriotic society have done much to instill local pride and further a cultural awareness of the local architectural heritage. It is hoped that the citizens of this community will go further in their efforts of saving dwindling numbers of early houses and buildings in this community.

f. Marking historic sites throughout the State. In the first and second decades of this century many citizens interested in Delaware's history advocated a system of marking historic sites such as were used in some of the other older states along the Eastern Seaboard. The proposal gained momentum and the first tangible effect was a publication by the National Society of Colonial Dames of America in the State of Delaware listing what they considered to be the more important historic sites in each community. In 1931 the General Assembly of Delaware passed an Act appointing a commission to erect historic markers in the State, and a sum of $20,000 was appropriated for that purpose. A commission of 5 members was appointed by Governor C. Douglass Buck, beginning its work immediately and finishing it June 30, 1933. As a result of their activities 152 highway type historic markers were erected and 25 bronze tablets were affixed to houses, buildings and similar historic sites. When the work of that commission was completed their records and duties were transferred to the Public Archives Commission. Since that time the Commission has added to these markers as public interest developed in a particular historic site. It has carried on the maintenance of these markers in conjunction with the State Highway Department when limited funds permitted. In Delaware, as in other states, this is an excellent medium of calling attention to our history and helping to preserve this part of our cultural heritage. More work needs to be done in marking remaining historic sites and it is hoped that funds will be made available for this purpose as it is one of our best means of advertising Delaware and informing our own public and those traveling through the State.

The examples briefly referred to above are, for the most part, museums, historic buildings or sites which are open to the public. There is also in our State a considerable number of old houses and buildings which are at present being taken care of through private ownership. Some of

these have historic connotations and others are significant as good examples of architecture of a particular period. Attention should be given to the future preservation of them.

The thousands of people who visit our museums, historic houses and sites each year, and those who attend the annual open-house days at New Castle, Dover, and Odessa are ample evidence of the prevalent interest in this aspect of vacationing and tourism. This is not a localized situation; it is a national trend of visitation to the more than 1,000 historic restorations throughout the country.

9.03 DEVELOPMENT OF HISTORIC RESOURCES

a. Promotion of tourism. Delaware does not have natural resources for vacation purposes like the Catskills or the Poconos of our neighboring states of the Delaware River Basin, but we do have improving park facilities and a rich natural resource in our lakes and ponds, and the river, bay and ocean beaches and coastline. This has been brought out ably in the other reports which are a part of the State Report. In nearby Virginia tourism, chiefly to the historic houses and sites, has become the principal industry of that state. After years of promotion and development of its tourist attractions, Virginia is planning promotional expenditures for 1958-1959 of $681,000 for tourism and $13,850 for industrial promotion. For the same period Delaware has budgeted $49,750 for both. Massachusetts, another state with a long, proud history, which is an important aspect of its tourist business, has budgeted $431,400 for tourism and $46,000 for industrial promotion. The adjacent State of Rhode Island plans to spend $4,865 for tourism and nothing for industrial promotion. Although not as pertinent, because historic sites are not as prominent as other tourist attractions, the comparable figures for our neighboring states are nonetheless important. During the period 1958-1959 New Jersey will spend $828,680 for tourism and $133,520 for industrial promotion; Pennsylvania, $394,650 for tourism and $30,000 for industrial promotion; Maryland, $56,685 for tourism and nothing for industrial promotion. May we correctly infer that these states, by spending more to promote tourism and vacationing, prefer it to industrial promotion? It would seem that Delaware has failed to recognize and capitalize upon a rich resource which we have inherited.

b. Tourism is big business. The report of a survey of the travel and vacation industry published by the Philadelphia Federal Reserve District, of which Delaware is a part, disclosed that about $600 million a year was spent in the district for tourism and vacationing during 1956. It is an industry exceeded in importance only by chemical manufacturing, primary metals, and agriculture. It should be noted that only the Rehoboth Beach area of Delaware is reported upon; other places apparently not being surveyed. This report also indicated that 63¢ of each vacation dollar was spent for lodging, eating, and in drinking places; 19¢ went to retailers for personal services; 7¢ was spent for transportation; and 11¢ for amusements. In Sussex County the tourist and vacation business amounted to between $5 and $10 million in 1956.

In 1949 Congress chartered the National Trust for Historic Preservation, an organization to aid and foster the restoration movement through

its staff of technical experts. The National Trust has acquired several historic houses which it administers and grants of $\$2\frac{1}{2}$ million have been given to its endowment. In a letter to Governor J. Caleb Boggs, the President of the National Trust stated: "National averages show that only 30 visitors per day will bring as much money into an historic community as a new industry with a $100,000 annual payroll."

c. Prosperity and progress. The editors of Fortune magazine in a careful study of municipal and suburban development have produced an important and provocative volume entitled The Exploding Metropolis. A portion from page 133 states: "In the next 3 or 4 years Americans will have a chance to decide how decent a place this country will be to live in, and for generations to come. Already huge patches of once-green countryside have been turned into vast, smog-filled deserts that are neither city, suburb, nor country, and each day--at a rate of some 3,000 acres a day-- more countryside is being bulldozed under. You can't stop progress, they say, yet much more of this kind of progress and we shall have the paradox of prosperity lowering our real standard of living."

Can we not in Delaware help conserve our water resources and avoid further industrial pollution by emphasizing agricultural land use, the conservation of natural resources, and the development of tourism through the conservation of our cultural resources rather than further heavy industrial development?

By way of our excellent State Highway system thousands of visitors come into Delaware each year. It is true that a considerable percentage are just driving through, but a sampling of them discloses that they find the rural scenery restful and attractive. Others come to our State from the surrounding metropolitan areas to enjoy our beaches, for fishing, hunting, historic sightseeing, and just to see fresh green countryside as an escape from the cities. Delaware can, in future years, continue to attract these people in greater numbers through greater development of its natural and cultural resources; a rich supply of potential wealth that has not been fully explored, let alone tapped. Through this type of promotion the water supply would be conserved as tourists require an insignificant amount as compared to the thousands of gallons used daily for industrial purposes.

Delaware, as one of the rapidly growing states, will naturally experience further industrial expansion, but, through the enactment of adequate zoning legislation for Kent and Sussex Counties, the type of industry could be regulated. Through the location of dry industries, research laboratories and distribution centers in the State, instead of wet industries, there would be a minimum of destruction. As a consequence, streams would not be filled with industrial waste, historic sites need not be bulldozed, small streams and marshes would not be filled in, wooded and green areas would still be attractive, and erosion and runoff would be decreased. It is true that during a recession the tourist economy would suffer, but conversely the tourists and vacationers would not appear on Delaware's relief or Unemployment Compensation rolls.

d. Other considerations. There is another aspect of water and land rights to which the State of Delaware has given little or no attention That is the riparian and underwater rights within the 12-mile

circle from New Castle. Any material dredged from the Delaware River within this area is the soil of the State of Delaware. In any project for the widening or deepening of the river channel, our State should lay claim to this soil for fill purposes. By planning ahead for its most advantageous use, historic sites such as the valuable Indian camp grounds at Naaman's Creek, or important marsh areas would not be filled in because it was expedient to do so. Furthermore, during the long history of transportation on the Delaware River, recited earlier, there were numerous ships and vessels sunk in the period of more than three centuries. The salvage from these wrecks, whether it be coins, bullion, or historical objects, should be rightfully claimed by the State and its policy well defined. In the summer of 1948 a dredge working in the Philadelphia area came in contact with a wrecked ship of the Revolutionary War period with the result that many valuable historical objects of that period were recovered. An article describing that incident was published in the Bucks County Traveler and is included in this report, on pages 9-13 and 9-14.

9.04 FUTURE CULTURAL PLANNING.

With the increases in population forecast for the years 2010 and 2060, there will naturally be an expansion of many types of facilities to care for this greater population. Even now highway planning is going forward, regional planning, zoning, housing developments, educational facilities, and similar accommodations for the enlarged population are in the planning stages. It can easily be foreseen that these greater numbers of people traveling about as tourists or vacationists will be seeking recreation. In the event that the projected tunnel under the Chesapeake Bay in the Norfolk, Virginia, area is constructed, the present Ocean Highway through Delaware will be a much busier artery of travel. Instead of having thousands of people use our highways to hurry through the State, we should plan tourist attractions to detain them here. There should also be planning of tourist and vacation facilities to bring people into Delaware in greater numbers than at present. The principal elements of future planning of this type could be the following:

a. Follow the example of nearby states and spend more funds to develop and advertise the rich potential in historic houses, sites, and museums for tourism. As a further example of what is being done nearby, Pennsylvania is planning to spend $150,000 for the restoration of Fort Mifflin, near Philadelphia, while Delaware is spending $10,000 a year on Fort Delaware, which had over 2,000 visitors in the latter part of the summer of 1958.

b. Make plans for the selection and future development of historic sites as tourist attractions.

c. Enact more historic zoning to protect the sites and natural resources from further encroachment.

d. Exercise more control of subdivisions and small housing developments so that the highways are not built up continuously from community to community.

e. Plan to reserve for industrial expansion the present area available in northern New Castle County along or in the vicinity of the

Delaware River where some industries already are located. Future needs for this purpose could well be located in the larger areas, already zoned as industrial, extending from the Christina River to Delaware City.

f. Reenact or strengthen billboard regulations in the manner being followed on throughways so that the landscape will be visible and attractive.

At the present time, with only publicity from the individual agencies concerned, there is an annual attendance of 148,490. This figure for 1958 includes the actual count at the Delaware Art Center, Henry F. du Pont Winterthur Museum, Hagley Museum, Historical Society of Delaware, Fort Delaware, Delaware State Museum, John Dickinson Mansion, Zwaanendael Museum, A Day In Old New Castle, and Old Dover Days. None of the statistics on tourism or travel which we have seen for Delaware take this attendance into consideration. The number of visitors to these museums and historic sites is increasing year by year and it may be expected confidently that this total of visitors will increase with each passing year.

As only 3 of these museums kept a daily record of the residence of those attending, the projection for future attendance will have to be based on the figures of the Delaware State Museum, John Dickinson Mansion, and the Zwaanendael Museum. We acknowledge the valuable assistance of the Delaware State Coordinators of this Survey in providing the population statistics and interpreting our available attendance figures. The following charts show the present source of visitors and the percentage as well as the mathematical projection of attendance with relation to population.

TABLE 1

Source of Visitors	Percentage
Delaware	46.7
Maryland, Pennsylvania, Washington, D.C., Virginia, New Jersey and New York	41.8
Remaining states and foreign	11.5

TABLE 2

Projection of Future Attendance

		1958	1965	1980	2010	2060
1.	Delaware State Museum John Dickinson Mansion Zwaanendael Museum	32,000	45,000	57,000	No estimate	No estimate
2.	Delaware Art Center Winterthur Museum Hagley Museum Historical Society of Delaware Fort Delaware A Day In Old New Castle Old Dover Days	116,490	130,000	145,000	No estimate	No estimate
3.	Total Visitors	148,490	175,000	202,000		

In conclusion, it should be emphasized that with the preservation of existing historical sites, the development of others, and concerted progressive advertising of these tourist facilities, as is done by our neighboring states and in Virginia, the number of visitors to Delaware could be greatly increased.

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BUCKS COUNTY TRAVELER, JULY, 1961

Revolutionary Relics Found In Sunken Boat in Delaware

(By Walter S. Hare)

A dredge working in the Delaware about ten miles below the Philadelphia-Camden Bridge, in the Summer of 1948, hit a sunken boat covered by 18 feet of silt. A diver, sent down to investigate, came up and made a surprise announcement --a ship's cargo 175 years old lay in the bed of the river.

"I think it was an English vessel, sunk during the American Revolution," said Captain Charles L. Phillips, of the dredge. Material from the wreckage seemed to bear him out. Thousands of hand-made nails of all sizes, iron and brass locks of British make in the period 1750-1775, pewter plates and spoons, shoe buckles, stirrups and bits for horses, candle snuffers, iron implements of many kinds--these were some of the relics pumped ashore by the dredge through a pipeline to the New Jersey side, near Thorofare.

Many were salvaged and are in historical societies now, or in hands of individual prospectors who dug in the sands for the treasure trove through August and September, 1948.

Identity of the ship wreck remains a mystery. It lay in deep water, 30 feet or more below the river's surface. There is speculation it was a British supply ship that ran afoul of Continental shore batteries or gun boats in the Fall of 1777 when the British occupied Philadelphia and were trying desperately to control the Delaware.

That winter, 1777-78, was the bitter plight of Washington's Army at Valley Forge.

In October and November, 1777, there was tremendous cannonading along the Delaware, as British and Hessians by

These relics date to 1777 or earlier. They were dredged from a sunken ship in the Delaware in 1948.

land and water laid siege to the patriot Fort Mercer, now National Park, New Jersey, and Fort Mifflin which is just above where Philadelphia Airport is today.

Two British fighting ships, the Augusta of 64 guns, and the Merlin carrying 18 guns, sank in the 1777 duelling. That was in the same location as the wreck brought up 171 years later by the American Dredging Company which had an Army contract in 1948 to deepen Mantua Creek Anchorage, above Paulsboro.

If the ship remains were the British fighters there is nothing to prove it. Not a single military or naval button or insignia was found. The stuff that came in from the pipe line from dredge to river side was curious and interesting, and unmistakably pre - Revolutionary. Every metal button salvaged was unmarked, however. The writer has, among the relics he found, a pair of cuff links in which is the figure of a dignitary with powdered wig. It could be George III. One coin found bears the likeness of the British Monarch. It is dated 1769.

Squat blown-glass wine bottles, some with the cork still sealed, came out of the sunken vessel. A diver brought up one and gave it to Captain Phillips, in charge of the dredge. Another bottle miraculously escaped the huge bladed cutter that tore into the river bottom where the ship and its cargo were buried.

The Gloucester County Historical Society, at Woodbury, made special effort to gather representative relics from the stricken ship. Its members, with shovel and screen, got several bushels of items. Some are being studied for identification and association.

Stamped on the metal pieces from the wreck were these markings: Murdock & Co., Loy, Duty, I B, Pit, Kettland, Crabtre, Port Rico. These and other identification symbols may, in time, serve to help solve the mystery.

PUBLIC ARCHIVES COMMISSION
Appendix I

The following historic sites are marked with either roadside type signs or bronze tablets as described in the published <u>Guide to Historic Markers in Delaware</u>.

NEW CASTLE COUNTY

Block House, N.C.-1

Robinson House, N.C.-2

Naaman's Creek, N.C.-3

Naaman's Bridge, N.C.-4

Newark Union, N.C.-5

Gunning Bedford, Jr., N.C.-6

Joseph Tatnall House, Bronze Tablet

Encampment of Continental Troops 1777, N.C.-7

Delaware Bank Building, Bronze Tablet

Old Town Hall, Bronze Tablet

Shipley House, Bronze Tablet

John Dickinson, Bronze Tablet

Sign of the Ship Tavern, Bronze Tablet

Asbury Methodist Episcopal Church, Bronze Tablet

Holy Trinity Church, Bronze Tablet

Old Swedes' Church, N.C.-8

The Rocks, N.C.-9

Eden Park, N.C.-10

Site of Crane Hook Church, N.C.-11

Long Hook Farm, N.C.-12

New Castle Common, N.C.-13

New Castle Common, N.C.-14

Buena Vista, N.C.-15

Buena Vista Bronze Tablet

Commodore Thomas Macdonough, N.C.-16

Old Drawyers, N.C.-17

Odessa, N.C.-18

Edmund Cantwell, N.C.-19

Indian Treaty, N.C.-20

New Castle, N.C.-21

Broad Dyke, N.C.-22

Site of Fort Casimir, N.C.-23

Site of Home of George Read,
Bronze Tablet

Packet Alley, N.C.-24

Gunning Bedford House,
Bronze Tablet

Landing Place of William Penn,
N.C.-25

New Castle and Frenchtown
Railroad, N.C.-26

Town Hall and Market House,
N.C.-27

The Green or Market Plaine,
N.C.-28

Van Dyke House,
Bronze Tablet

Historic Museum,
Bronze Tablet

New Castle and Frenchtown
Railroad, N.C.-29

New Castle, N.C.-30

New Castle, N.C.-31

Saint Mary's Church, N.C.-32

Washington's Earthworks,
N.C.-33

Robert Kirkwood, N.C.-34

Newark Academy, N.C.-35

Old College,
Bronze Tablet

The Wedge, N.C.-36

The Wedge, N.C.-37

Mason and Dixon's Tangent Stone,
N.C.-38

Welsh Tract, N.C.-39

Welch Tract Church, N.C.-40

American Position, N.C.-41

Battle of Cooch's Bridge,
Bronze Tablet

Cooch House,
Bronze Tablet

British Position, N.C.-42

Aiken's Tavern, N.C.-43

New Castle and Frenchtown
Railroad, N.C.-44

Washington Dined Here, N.C.-45

Samuel Davies, N.C.-46

Welsh Tract, N.C.-47

Caesar Rodney's Camp, 1777,
N.C.-48

Washington's Fortifications,
N.C.-49

Meeting Place of Washington's
Officers, N.C.-50

Lafayette, N.C.-51

Talbot's Fort,
Bronze Tablet

Samuel Patterson, N.C.-52

Washington's Reconnaissance,
N.C.-53

Iron Hill, N.C.-54

Mason and Dixon Line, N.C.-55

Bethel Church, N.C.-56

The Bear, N.C.-57

Pencader Church, N.C.-58

Old Feeder Canal, N.C.-59

Dupont Powder Mills, N.C.-60

Wilmington, N.C.-61-69

Swanwyck, N.C.-70

Oliver Evans, N.C.-71

Duncan Beard, N.C.-72

River Road, N.C.-73

Old St. Anne's P. E. Church, N.C.-74

Presbyterian Church, N.C.-75

KENT COUNTY

Duck Creek Hundred, K.-1

Commodore Jacob Jones, K.-2

Duck Creek Hundred, K.-3

Little Creek Hundred, K.-4

Little Creek Hundred, K.-5

Kenton Hundred, K.-6

Kenton Hundred, K.-7

Little Creek Hundred, K.-8

East Dover Hundred, K.-9

West Dover Hundred, K.-10

East Dover Hundred, K.-11

West Dover Hundred, K.-12

Ridgely House,
Bronze Tablet

Site of King George's Tavern,
Bronze Tablet

Caesar Rodney,
Bronze Tablet

Nicholas Ridgely,
Bronze Tablet

East Dover Hundred, K.-13

North Murderkill Hundred, K.-14

North Murderkill Hundred, K.-15

South Murderkill Hundred, K.-16

Capt. Jonathan Caldwell, K.-17

John M. Clayton,
Bronze Tablet

Colonel John Haslett,
Bronze Tablet

South Murderkill Hundred, K.-18

Mispillion Hundred, K.-19

Mispillion Hundred, K.-20

East Dover Hundred, K.-21

North Murderkill Hundred, K.-22

North Murderkill Hundred, K.-23

South Murderkill Hundred, K.-24

Barratt's Chapel, K.-25

South Murderkill Hundred, K.-26

Milford Hundred, K.-27

Milford, K.-28

Milford, K.-29

Milford Hundred, K.-30

Milford Hundred, K.-31

Belmont Hall, K.-32

Home of John Dickinson, K.-33

Dover, K.-34

Dover, K.-35

Dover, K.-36

Dover, K.-37

Dover, K.-38

Old Christ Church, K.-39

Woodburn,
Bronze Tablet

Presbyterian Church,
Bronze Tablet

SUSSEX COUNTY

Northwest Fork Hundred, S-1

Northwest Fork Hundred, S.-2

Seaford Hundred, S.-3

Seaford, S.-4

Seaford, S.-5

Seaford Hundred, S.-6

Broad Creek Hundred, S.-7

Laurel, S.-8

Broad Creek Hundred, S.-9

Little Creek Hundred, S.-10

Laurel, S.-11

Little Creek Hundred, S.-12

Cedar Creek Hundred, S.-13

Milford, S.-14

Cedar Creek Hundred, S.-15

Georgetown Hundred, S.-16

Georgetown, S.-17

Georgetown, S.-18

Georgetown Hundred, S.19

Dagsboro Hundred, S.-20

Dagsboro, S.-21

Dagsboro Hundred, S.-22

Baltimore Hundred, S.-23

Baltimore Hundred, S.-24

Cedar Creek Hundred, S.-25

Milford, S.-26

Cedar Creek Hundred, S.-27

Broadkiln Hundred, S.-28

Broadkiln Hundred, S.-29

Lewes and Rehoboth Hundred, S.-30

Lewes, S.-31

Lewes, S.-32

Lewes, S.-33

Lewes, S.-34

Lewes, S.-35

Ryves Holt, Bronze Tablet

Old Court House, Bronze Tablet

Georgetown, S.-36

Georgetown Hundred, S.-37

Broadkiln Hundred, S.-38

Broadkiln Hundred, S.-39

Lewes and Rehoboth Hundred, S.-40

Georgetown Hundred, S.-41

Nanticoke Hundred, S.-42

Nanticoke Hundred, S.-43

Broad Creek Hundred, S.-44

Broad Creek Hundred, S.-45

Georgetown, S.-46

Georgetown Hundred, S.-47

Nanticoke Hundred, S.-48

Nanticoke Hundred, S.-49

Seaford Hundred, S.-50

Northwest Fork Hundred, S.-51

Dagsboro Hundred, S.-52

Indian River Hundred, S.-53

Indian River Hundred, S.-54

Lewes and Rehoboth Hundred, S.-55

Dagsboro Hundred, S.-56

Gumboro Hundred, S.-57

Gumboro Hundred, S.-58

Dagsboro, S.-59

Dagsboro, S.-60

Dagsboro Hundred, S.-61

Baltimore Hundred, S.-62

Old Christ Church, S.-63

Bethel Church, S.-64

PUBLIC ARCHIVES COMMISSION
Appendix II

Aside from Indian sites, which are not being listed for fear they might be despoiled by souvenir hunters, there are listed below those old houses, buildings, and historic sites which are worthy of consideration for historic preservation before any construction projects are contemplated. As this survey has attempted to show, these cultural resources are invaluable as a means of raising revenue in Delaware if utilized properly.

Checklist of Historic Sites

Supplementing

Guide To Historic Markers In Delaware

NEW CASTLE COUNTY

Mouth of Naaman's Creek, about ½ mile south of State Line. Aboriginal fish weirs found here, damaged by subsequent dredging, have never been fully studied. The site shows extensive Indian occupation. Naaman's Creek valley west to the vicinity of Arden is likewise a partially investigated region of Indian occupation.

"Wren's Nest" (Darley Mansion), at Darley Road, about 1½ miles from the Pennsylvania Line, was the home of the famous illustrator Mr. Felix O. C. Darley after his purchase of it in 1850.

George Lodge House, 2½ miles from the Pennsylvania Line, on US 13, was the Delaware home of the novelist Anne Parrish.

Grubb Homestead, on Grubb's Road north of Arden, built in sections between about 1700 and 1760, is still of architectural interest although badly damaged by fire.

Bellevue Quarry, now a reservoir, about 2 miles from Claymont, supplied the granite to build the Delaware Breakwater (1828-1832).

Tussey House (on Penny Hill), built in 1765, was a major Methodist meeting place during the period when the church was being organized in America. The famous evangelist Captain Thomas Webb preached here in 1769.

Shaw House (on Penny Hill) was the home of Robert Shaw, famous Delaware etcher and illustrator.

Chester-Bethel M.E. Church on State Route 261, near the present church, a small stone structure erected in 1799 to replace a chapel of 1780 is still standing, used as a shed. Thomas Webb and Francis Asbury preached here.

Perry's Tavern, on Concord Pike, about 1 mile from the Pennsylvania line, an early 19th-century stagecoach stop, is still used as a tavern.

"Lombardy," on Concord Pike a quarter-mile above Blue Ball, was built before 1793, and was once the home of Gunning Bedford, Jr., Federal jurist and statesman.

Blue Ball Tavern, now a private residence, was an inn from before 1800.

Friends Centre Meeting House, 1 mile off Kennett Pike on a side road 0.1 mile south of Centreville, was built in 1796 to serve a Monthly Meeting in existence since about 1690. It is almost unaltered both inside and out, and is an excellent example of meeting house architecture in the area.

Lower Brandywine Presbyterian Church, Kennett Pike ½-mile north of Winterthur, built in 1859 to serve a congregation organized in 1720.

Mermaid Tavern, Limestone Road, 3½ miles from the Pennsylvania line, now private, was an inn as early as 1740; despite numerous alterations it retains many of its distinctive original features. It was a post office, polling place, and neighborhood meeting place in the 19th century.

Red Clay Creek Presbyterian Church, on Del-Castle Farm road, 1½ miles off Route 7, built in 1853, in part from the materials of a mid-18th-century predecessor.

Murray House, on Route 7, 2 miles east of Mermaid Tavern, predominantly late 18th-century, has a log wing with a fireplace, date 1741.

In the Village of Stanton, four 18th-century buildings are listed in the Delaware Guide: a brick house on the southeast corner of the main intersection was a tavern in 1797; the Tatnall (Byrnes) House on Old Mill Road is of Dutch Colonial pattern and dates from about 1750; a stone school house adjoining the Friends Meeting was used in the early 19th century or earlier; and the Marshall House is one where Washington is said to have dined during the 1777 campaign.

Boyce House, on White Clay Creek, a mile from Stanton, built before 1775, is a notable example of Georgian Colonial architecture.

Bread and Cheese Island is of interest as a landmark, known by its present name since the 17th century, as shown by its appearance on Lindestrom's map of 1656.

The Village of Christiana, once at the head of navigation, was a milling, transportation, and craft center through the 18th and early 19th centurie[illegible]ason & Dixon met the commissioners of Pennsylvania and Maryland there [illegible] discuss boundary problems in 1765, and Washington frequently stopped there on north- or south-bound journeys. Eighteenth century buildings specifically listed in the Delaware Guide are the Christiana Hotel and the Shannon Hotel.

Patterson (Buford) Mill on Cooch's Bridge Road, operated from 1795 to 1924, and was a milling site from 1705. The nearby miller's house was erected before 1740.

Josiah Lewdon House, on Route 7 just east of Christiana, built in 1770, is a handsome Georgian structure with many original details.

Old Walnut Green Schoolhouse, on Route 82, about a mile west of Kennett Pike, was built about 1780, and is typical of the early schools of the region.

Hockessin Friends' Meeting, on Valley Road, near Route 41, erected in 1738 and enlarged in 1745, is an excellent example of midcolonial meetinghouse architecture. It retains the stepping blocks and carriage sheds of earlier days, and has an ancient cemetery with exceptional boxwood.

In the Town of Newport, once a shipping center of considerable importance, are the following early buildings: an inn at the northwest corner of James and Market Streets, praised in 1788 by former Governor John Penn; the adjoining "double house" on Market Street, of unknown date, featured by interesting brickwork; the Myers (Parkin) House, southeast corner of Market and Johns Streets, built in sections in the middle and later 18th century, with fine interior woodwork and good architectural design; and the Galloway House, on the west side of Johns Street, built about 1730, probably by the same craftsman who worked on the oldest portion of the Myers House.

Two houses on and near the old Newport Pike, built by members of the Richardson family, are "Glynrich" in 1765 and "the Brick Mill House" probably in 1723. In the latter, John McKinly, first Governor of Delaware, courted his future wife. Both buildings are of architectural interest.

Coffee Run Cemetery, southeast of Hockessin, was established by 1786; it is the earliest known Roman Catholic burial ground in the State. Nearby is the Father Kenny House, of stone and frame construction, built in 1812 as the home of a pioneer Catholic priest in Delaware.

Additional early buildings in the Richardson Park region are: "Rockwell," 160 Winston Avenue, built in 1813; an old stone house, 407 Winston Avenue, once on the "Rockwell" estate, probably an early Walraven residence; "Ashley," 15 Ashley Place, built in 1804, an outstanding example of late colonial architecture; "Woodstock," 102 Middleboro Road, has one wing probably erected in 1743.

"The post marked West," 3 miles west of Milford Crossroads, is a marker placed June, 1953, indicating the position of a basic reference point in the Mason-Dixon survey.

Prismatic Stone, erected in 1849 by the Graham survey, marking the southern point of the Wedge, is near where Route 896 crosses the Maryland-Pennsylvania line.

Head of Christiana Presbyterian Church, on Route 273, two miles beyond the B & O RR crossing, was built in 1858 to serve a congregation which has worshipped on the site continuously since 1708.

Minot Curtis House, believed to be very old, stands near the Curtis Paper Plant, on land patented in 1684.

White Clay Creek Presbyterian Church, on Route 2 at Polly Drummond Hill, was built in 1853 to serve a congregation in existence since 1720; near the top of the hill is the site of the original church, with its still-existing cemetery.

Andrew Gray House, near Route 2 on Polly Drummond Hill, was built in the later 18th century, and retains many notable architectural features.

England Manor House and mill are on White Clay Creek, about ½-mile off Route 2, the house was built in 1747, with excellent architectural features; the present mill, in 1789 or earlier, replacing former mills on the same site.

St. James Episcopal Church, on Route 2, 2½ miles from Marshallton, was erected in 1820 to serve a parish existing since 1717. It is a good example of Greek Revival church architecture.

Swedish type log house at Price's Corner, near Marshallton, was probably erected in the 17th century, and is of architectural interest.

Greenbank Mill near the New Castle County Correctional Institution, and about 3/4 of a mile off Route 2 at Price's Corner, built partly in 1790 and partly in 1812, is one of the few still in operation in Delaware; some of its original machinery was bought from Oliver Evans.

Marsh Road from Naaman's Road to Washington Street Extension.

Old stone mill and millpond where Naaman's Creek crosses Marsh Road at Arden, now used by Arden Water Company as a pumping station and reservoir. The walls, millpond and race are in their original condition; the interior has been rebuilt. There is an old stone house, presumably the miller's quarters, a few hundred yards distant. This adjoins the Grubb homestead tract.

Old stone house at Grubbs Corner, extensively renovated; a blacksmith shop once adjoined it; a double frame tenant house, facing Grubbs Road, is still standing.

Log house, two-story, now clapboarded, with a massive stone barn, and a stone dairy dated 1795, the latter now converted to a separate dwelling, about midway between Grubbs Road and Silverside Road.

Log House at the corner of Marsh and Silverside Roads; local tradition called it the oldest house in the vicinity.

Old stone house, very well proportioned, at Veale and Marsh Roads.

Forwood School, on Silverside Road near Marsh Road, was built in 1796 as a neighborhood schoolhouse and used as Public School District #5 from 1829 until about 1935. It has since been converted to a private dwelling without substantial exterior change. (There is another of these stone schoolhouses at Claymont, as well as the one in Brandywine Village; there are possibly others in the Hundred. They appear to have stemmed from the early public school movement reflected in the Constitution of 1792 and the School Fund Act of 1796.)

Stone house, Carrcroft, north end, a large handsome building, possibly circa 1790.

Two stone houses between the B&O tracks and Washington Street, both very close to Marsh Road, one with its gable end to the road, the other facing it, at the southwest corner of Bringhurst woods.

Grubbs family burial ground at Arden has some 18th-century grave markers.

Reynolds house, at Ardencroft, said to be circa 1790 with good interior woodwork, and a stone springhouse across the road, now converted to a dwelling.

Conly house, said to be built around an earlier log house which is still intact.

WILMINGTON

Alrichs house, on the Christina River, near the Delaware, with a dated brick addition (1785) to a frame building believed to have been erected in the 17th century, was long associated with the Poulson and Alrichs pioneer families.

The buildings at 1203-1205 Market Street, and the block from 13th to 14th Streets, on the west side, represent five surviving dwellings of a once-fashionable neighborhood. All are excellent examples of early 19th-century domestic architecture.

Jacob Starr house, 1310 King Street, was built in the period before 1806, the year it was purchased by a sea-captain from its builder, is well preserved both inside and out, and exhibits several excellent architectural features.

First Presbyterian Church (now Colonial Dames House) on Park Drive at West Street, was built in 1740 to serve the Presbyterians

of Wilmington and its vicinity; it was moved from its original location on Market Street below Tenth in 1919, while the graves in its churchyard were transferred to the Wilmington-Brandywine Cemetery. The church is an excellent example of church architecture of its period; its congregation included a number of notable early residents.

Old fording place, at the foot of Adams Street, was the original Brandywine crossing into Wilmington, before the erection of a bridge in 1764.

Rockford Village, near the Bancroft Mill, is an interesting survival of an early nineteenth-century mill-workers' community.

Hagley Foundation, comprises an area along the Brandywine preserving and restoring a major section of one of the country's earliest important industrial sites.

Brandywine Village, a major milling center in the eighteenth and earlier nineteenth centuries, is represented by a number of surviving buildings, most of them the homes of prosperous millers built in the generation of the Revolution, and all excellent examples of the building styles current at their dates of construction. They include:

Derickson House, 1801 N. Market Street, built about 1771.

Joseph Tatnall House, 1803 N. Market Street, built about 1770; Washington and Lafayette, acquaintances of the first owner, visited here, the former on several occasions and the latter twice.

Edward Tatnall House, 1807 N. Market Street, built about 1790, probably as an extensive addition to a much older dwelling believed to survive as the rear section of the present structure.

William Lea House, 1901 N. Market Street, is of early nineteenth-century design, as is the

William Smith House, 1905 N. Market Street, erected in 1801.

Brandywine Academy, 5 Vandever Avenue, erected in 1796 on land deeded for the purpose by John Dickinson and John Welsh, has been successively an academy, probably supported by neighborhood subscription, the district schoolhouse under the Free School Act of 1829, and a branch of Wilmington Institute Free Library. The building has been a community meeting place through much of its lifetime, and has at times been used as a place of worship on Sundays. It is one of a small group of substantial schoolhouses apparently built in response to the pioneer, and abortive, public school movement of the 1790's.

Cathedral Church of St. Johns was erected in 1857 on the site of a notorious tavern, a spot chosen with specific intent.

Simms House, NE corner of 4th and King Streets, erected about 1720, is one of the few old buildings in the area recognizable as once having

been a fine residence; it was the home and shop of Drs. John Simms and John Henry Simms, apothecaries and physicians.

Captain Thomas Mendenhall House, northwest corner of Front and Walnut Streets, built in the early 19th century, is an unusual survival of a large down-town house; several original interior features remain.

St. Andrews Church was built in 1840 to replace an 1829 building destroyed by fire.

Washington's Headquarters, 303 West Street, was marked by the Society of the Cincinnati.

St. Peters Roman Catholic Pro-Cathedral is the product of repeated enlargement and renovation of the first Catholic Church in Wilmington, erected in 1816; it became the cathedral when the diocese was established in 1868.

Friends Meeting House and burial ground, the block between Washington, West, 4th and 5th Streets, stand on land occupied by the Friends for religious purposes since 1738; the present structure was erected in 1816 to replace one dating from 1748; parts of the earliest meeting house (1738) are incorporated in the building opposite, the former Friends' School. The burial ground contains the graves of many notable residents, among them John Dickinson.

The Woodward Houses, 701-703 West Street, date respectively from 1745 and 1760. The house at 703 has a hearthstone of particular interest.

Cool Spring Park contains many rare botanical specimens among its trees, nearby is an unusual oak tree, the last survivor of a grove famous as a picnic ground in the Revolutionary period.

Tilton House ("Federal Hill"), southwest corner of 9th and Broom Streets, was built in 1802 by Dr. James Tilton, a very distinguished Delaware physician, on a site which was among those considered for the Federal Capitol; subsequently enlarged.

Wilmington and Brandywine Cemetery was established in 1843. In addition to the graves of notable Delawareans, it has a magnificent Cedar of Lebanon which was brought from Palestine in 1850, now one of the finest specimens in the United States.

NEW CASTLE

The blocks between the waterfront, 4th, Delaware, and Harmony Streets contain 38 buildings or historic sites ranging in date from the middle 17th to the early 19th centuries. The total area comprises a unique survival of an American colonial capital virtually in its late 18th century condition. Specific descriptions of the individual buildings and sites appear in New Castle on the Delaware, 1951 edition, pages 64-101.

Points of interest outside these boundaries include: Spread Eagle Hotel, 2nd Street north of Harmony, highly typical of colonial taverns of the region.

The Broad (horse) Dyke, begun about 1655, providing a northbound causeway across the marshes, which in 1675 became part of the King's Highway. In 1701, the terminus of this dyke was used as the center for the first survey of the 12-mile circle. There is also a Narrow (foot) Dyke near the River, contemporary with the Broad Dyke.

"The Hermitage," near William Penn School, was built in three sections, viz., 1700 or earlier, about 1747, and 1818. The latest portion was added by Senator Nicholas Van Dyke. All three are architecturally interesting.

The Deemer House, NW corner of 6th and South Streets, built about 1850, is an outstanding example of the architecture of its period. Its surrounding park contains a number of rare and valuable specimen shrubs and trees.

Immanuel Church Glebe House, River Road, ½ mile north, was erected as a parsonage, on land bequeathed to the parish in 1719 and now used in part as a burial ground.

"Boothhurst," River Road 1½ miles north from ferry, an early eighteenth-century residence enlarged in 1842, is interesting both architecturally and as the home of the artist Laussat R. Rogers. It is surrounded by a sixty-acre tract of woodland, in part primeval, continuously in woodland since the early colonial period, a circumstance unique in this region and consequently of botanical significance.

Regency House ("Swanwyck"), between River Road and US 13, erected about 1825, and probably designed by a French refugee, is architecturally unusual despite modern alterations.

"Spring Garden," on Hare's Corner Road, built by Richard McWilliams about 1750, has fine original woodwork.

Nivin House, built in 1760; and the Mansion House, built in 1750, are notable colonial houses on River Road.

A substantial proportion of the other farmhouses in the vicinity of New Castle, in addition to those singled out for description, are believed to be old, some possibly dating even from the Swedish and Dutch periods and several from before 1680. Architects believe there are more buildings dating from the earliest American period on these farms than can be found in a similar area anywhere else. (<u>New Castle-On-Delaware</u>, 1951).

NEW CASTLE COUNTY BEYOND WILMINGTON

"Stockford," on US 13 at 2.7 miles below Wilmington near Hare's Corner, built about 1840, was the home of General James H. Wilson, distinguished for his Civil War services, who became a Delaware resident. East of it is an older brick dwelling once the home of John Stockton.

"Damascus," a brick farmhouse about $7\frac{1}{2}$ miles south of Wilmington, built about 1790, was the home of Jesse Higgins, an early 19th-century publicist and political leader.

Dragon Swamp, bordering Dragon Run, is important for conservation purposes as a favorite nesting-ground for wood ducks.

Sutton House, St. Georges, built 1802, is of architectural interest; it is still occupied by the builder's descendants.

Macdonough House, at Macdonough ("The Trap"), is the birthplace of Commodore Thomas Macdonough, a distinguished officer of the War of 1812. A family burial ground remains on the property.

The Village of Odessa has a considerable group of colonial buildings. Notable among them are:

David Wilson Mansion, on Main Street near 2nd, now a library and museum, was designed by the architectural firm of Robert May & Co., London, England, about 1769. Among its features are especially fine original paneling.

Corbit House, on Main Street near 2nd, built in 1773 upon plans drafted by Robert May, has undergone very little alteration through the years; in 1940 it was completely restored to its 18th-century form. Many consider it the finest example of a handsome late colonial dwelling remaining in Delaware.

Odessa Hotel, now private, was built in 1822; much of the original woodwork is intact. At the rear is a small pre-Revolutionary house of architectural interest; both are in course of restoration.

Old Public School, Odessa, is an unusual survival of a good town school building of the middle 19th century. Its older section was erected in 1844.

Friends Meeting House was erected 1783 for the use of the Duck Creek Meeting and recently has been restored to use after long neglect. This building was a station of the Underground Railroad.

"Fairview," built in 1773 a mile east of Odessa, across the causeway is a third house in the vicinity designed by the firm of Robert May.

Lore House, with an original portion built of logs about 1740, has interesting architectural details; it was once the home of Chief Justice Charles B. Lore.

Mailly House, built about 1770.

Pump House, built about 1772, with interesting architectural details; once a store and lodge room.

A frame and log house, occupied by J. A. Loven, built about 1740.

January House, built before 1773, and recently restored.

A brick house with later frame addition, dates of erection are not yet established; the frame portion is believed to have been the original manse of Old Drawyers Cnurch.

Thomas House, the original portion of which was built about 1740, of hand-hewn logs, has numerous interesting structural details.

Brick Store Landing, on Duck Creek, reached by a side road 4.7 miles below Blackbird, was once an important shipping point. It is marked by a large building still structurally intact, built in 1767 as a hotel, later converted to a store, and long a center of community life for the neighboring countryside. Some original interior details remain.

Clearfield Farm ("New Bristol"), built about 1755 near Brick Store Landing, was successively the home of David, William, and John Clark, all militia officers, the last of whom was Governor of Delaware 1817-1820.

Delaware City, though not among the early settlements in the State, has several points of historic or architectural interest:

Canal Lock, in Battery Park, Delaware City, marks the original terminus of the Chesapeake and Delaware Canal. Across the street is the Delaware City (Lower) Hotel, now private, which was built in 1828 and is the outstanding structure of the town's boom years which still survives. The Maxwell House, at Adams and William Streets, built in the form of a ship about 1850 by a steamboat captain, is an architectural curiosity. Fort du Pont and Fort Delaware were long the principal harbor defenses of the Delaware Valley. Just south of the canal is a holly tree whose size makes it an exceptional botanical specimen.

Stewart House, Port Penn, built about 1750, is said to have been struck by a cannon ball, according to one account, during the Revolution and by another account it was struck during the War of 1812. It has been the home of seven physicians of the Stewart family, extending through much of the life of the dwelling.

Huguenot House, near Taylor's Bridge, built in 1711, is an excellent example of early colonial architecture, with much original woodwork.

Liston House, 2.7 miles east of Taylor's Bridge, erected in 1739, is a good specimen of the architecture of its period. There is documentary evidence of its having been plundered by pirates in 1747.

Buck Tavern, near the Chesapeake and Delaware Canal at Summit Bridge, was a major inn for travelers between Maryland and the north. Washington's journals record a number of stops he made here. A Hessian general made it his headquarters during the campaign of September, 1777.

Middletown Academy, erected in 1826, has been both a private academy and the district public school building; Middletown Hotel, on the site of a tavern built in 1761, retains some of the walls of its predecessor;

Cochran Grange on Route 4, 1.2 miles from Middletown built in 1845, the home of Governor John P. Cockran, is an excellent example of a fine midnineteenth-century country home.

St. Anne's Church, near Middletown, was built in 1768 to serve a congregation founded in 1705.

Noxon House, near St. Andrew's School, was built in 1740; the vicinity was the site of important colonial fairs.

KENT COUNTY

E. Spruance House, on Commerce Street in Smyrna (east of Main Street), once housed the neighborhood bank. The oldest section was completed before 1791, and has several distinctive architectural features.

Abraham Pierce House, opposite E. Spruance House, is an excellent example of a small mideighteenth-century brick dwelling.

Lockwwod House, also in Smyrna, on Main Street north of Mt. Vernon Street, was, by tradition, a militia barracks of the War of 1812.

Cummins House, also on Main Street north of Mt. Vernon, and the adjacent Presley Spruance House, erected in the early nineteenth century, are typical of the homes of prosperous merchants in the years when Smyrna was an important shipping point.

Mustard Mansion, near the western end of Mt. Vernon Street.

"Belmont Hall," on the east side of US 13 south of Smyrna, was erected in part about 1684, and in part about 1753. It was the home of John Collins, a Revolutionary officer and Governor of Delaware.

"Woodlawn," just south of "Belmont Hall," is a brick colonial house with a midnineteenth-century addition, long the property of the Cummins family, and architecturally interesting.

Loockerman Hall, Delaware State College, just north of Dover, originally the mansion house of Nicholas Loockerman, was built about 1740; now used as a dormitory.

DOVER

"Woodburn," the residence of Mr. and Mrs. Thomas W. Murray, is a historic house of beautiful 18th century architecture. Built by Charles Hillyard, who married the daughter of Chancellor Killen. This was the scene of Patty Cannon's raid as told by George Alfred Townsend in "The Entailed Hat," and was a station of the Underground Railroad. Ancient trees and old boxwood beautify the grounds.

The Green. Laid out in 1717 in accordance with William Penn's order of 1683. Here the early markets, fairs, and slave markets were held, and here, at the time of the Revolution, the First Delaware Regiment was mustered before marching to join Washington's Army in the North.

Throughout the history of Delaware The Green has been the background for many of its important episodes, including the reading of the Declaration of Independence, at which time the portrait of King George III was burned in a public ceremony. At the close of the Revolution many of the Delaware troops were mustered out here, and on January 23, 1800, John Vining delivered an eulogium on the death of George Washington.

Notable among the old houses around The Green is the one in the southeast corner, built in 1812, by James Sykes, a noted surgeon. Eminent lawyers who have occupied this house were Chief Justice Thomas Clayton, Judge George Fisher, Nathaniel B. Smithers, Dr. Thomas C. Frame, and Chancellor John G. Nicholson.

In the northwest corner of The Green the Reverend John Miller, pastor of the Dover Presbyterian Church, built a house prior to 1780. His sons, Professor Samuel Miller, the first president of Princeton Theological Seminary, and Dr. Edward Miller, a Revolutionary surgeon, lived here. For many years this was the residence of the Saulsbury family.

On the north side of Bank Lane and The Green is a brick house built about 1740 among whose residents were John Banning, Caesar Rodney, and Dr. James Tilton. Opposite is the old Farmers Bank Building, where the bank first opened for business in 1807. Next to it is the site of the old home of Richard Bassett, a Delaware Governor, statesman and large landowner.

Residence of Mrs. Henry Ridgely. The house, made of brick laid in Flemish bond with glazed headers, was built in 1728 by Thomas Parke of Virginia. Bought by Charles Ridgely in 1767, the family has been in possession of the house ever since. The house features a typical 18th-century structure with simple paneling and wide-board floors.

Old State House, the second oldest in the United States which is still in use as a State House. Here Delaware ratified the Federal Constitution, December 7, 1787, becoming the first State to enter the Union. Built in 1722 as the Court House of Kent County, it was rebuilt in 1792 and restored in 1909. Since 1777, capitol of Delaware, used by both State and County governments until 1873, when the County relinquished its claim. Fine early portraits of George Washington and Delaware statesmen. Old bell of 1763, hung here by Thomas Rodney in 1770, was used to assemble "the freeholders of Kent at the Court House in the town of Dover, to take into consideration the acts of the British Parliament in shutting up the Port of Boston."

Kent County Court House, (1874), built on the site of an early court house, in 1691 ordered "burnt to gett ye Nailes," remodeled in 1918. Site occupied in 18th and 19th centuries by a series of inns. Exhibit of 18th century wills and deeds. Fine portrait of John M. Clayton, American statesman and founder of the modern Delaware judiciary system, in court room on the second floor.

Loockerman-Bradford House. Residence of Mr. and Mrs. William Bradford and Lucinda Bradford Shakespeare. Built 1742 by Vincent Loockerman, Kent County landowner and legislator, great-great-grandfather of present

owners. Early 18th-century paneling and china cupboards. Fine collection of Philadelphia Chippendale mahogany chairs, tables, mirrors, Duncan Beard clock, export china, and Gostelowe type chest-on-chest still in use by family.

The Rectory, (circa 1770), residence of the rector of Christ P. E. Church since 1879. The building was owned in 1776 by James Bellach, a captain in the Continental service from Kent County. In 1806 Charles Kimmey opened a store here.

Christ Church (1734). Founded by the English Society for the Propagation of the Gospel in Foreign Parts after a memorial signed by 22 inhabitants of Dover was sent to the Bishop of London in 1703. Central portion of the church dates from 1734; church por[illegible] the [illegible]stry, dates from about 1740. Chancel and choir rooms were added in 1887 and later. Organ music is played at intervals throughout the day. In the churchyard is a monument to Caesar Rodney, "The Signer," and tombs of the Ridgely family. The earliest grave is that of Captain Thomas Benson, of Whitehaven, England, 1748.

Number 49, The Green, was Dover's first post office, and it is believed to be among the older buildings on the square.

Number 508 South State Street, a small brick dwelling with a Dutch roof, is possibly one of the oldest in the town.

Number 523 South State Street is a large colonial house, once the home of John Banning, and long the Dover Academy. The interior has been altered substantially.

The Delaware State Museum. The main building is the restored Presbyterian Church of 1790, on Meeting House Square, ordered laid out by William Penn. Distinctive features of the church still intact are the circular stairway to the gallery and belfry and a corner alcove furnished with old pews, a memorial tablet to the first minister, the Reverend John Miller, communion silver, and two original tin sconces. In this and the second building, in addition to exhibits on Delaware's Indians, natural resources, industry, and agriculture, commerce and transportation, there are displays of early life in the State, as shown by period furniture, Delaware silver, woodworking tools, costumes, and volunteer firemen's mementoes; some exhibits from Fort Delaware are also to be seen. In the recently-opened third building is an early Swedish-type log house, of the kind that originated in Delaware, a grist mill, blacksmith shop, and cobbler's exhibit.

"Eden Hill Farm," 1749, is the residence of Mr. and Mrs. J. E. Scheller. Built in 1749 by Nicholas Ridgely, it is still owned by his descendants; it features a boxwood garden from 1790, and fine lanes of ancient trees; early type barn and bathhouse.

On North Little Creek Road, about 4 miles east of Dover, is a group of colonial brick houses known as "Cherry Valley," "Willing Brook," and Price Farm, near the now-abandoned Little Creek Friends Meeting, erected in 1802 to serve a congregation formed in 1711, with an adjacent cemetery.

Leipsic, first laid out as a village in 1723, provides an unusual example of a small maritime community not greatly altered from its mid-nineteenth century appearance.

"Wheel of Fortune," south of Leipsic on Route 9, is a colonial dwelling of architectural interest, with interior woodwork in excellent condition.

"Pleasanton Abbey," on Route 9 about a mile from "Wheel of Fortune," built about 1750, is another fine 18th-century manor house of architectural interest. It was the home of a notable Tory during the Revolution.

"Chipping Norton," opposite "Pleasanton Abbey," once the home of Charles Marim, is a third fine country house in the vicinity.

The Octagonal Schoolhouse, about 1½ miles south of "Chipping Norton," built in 1836, is a rare example of early public school architecture in Kent County.

The John Dickinson Mansion, built in 1740 by Samuel Dickinson, and the home of his famous son, John Dickinson, at many periods of his life, is a particularly fine example of mid-18th century plantation architecture in addition to its historical interest.

"Town Point," on St. Jones River, is a small, very early brick and frame house, believed to have been erected before 1680 and to have been the dwelling in which the first courts of the County were held. Shortly afterwards a tavern was established here.

Nowell House, Little Creek, is of colonial date, probably the oldest house in the community, and notable for its stone construction in an area devoid of native building stone.

Hoffecker House on State Route 6, 1½ miles west of Clayton, is of pre-Revolutionary construction, a good example of the early brick dwellings of the area.

"Mount Airy," Route 6, about a mile west of the Hoffecker House, is a mid-18th century plantation house on "Deer Park" tract, of brick with a frame addition of later date. Much of its woodwork is very early. It was once a bank.

Hazell House, about ½ mile east of the Maryland line, is another dwelling originally on the "Deer Park" tract, also of 18th century construction, with much of the original woodwork and fittings remaining.

"Bannister Hall," near the junction of Routes 6 and 300, is an unusual example of the frame country mansions of the Victorian period; behind it is the original brick mansion of the plantation, built about 1750.

"White House," about 2 miles southwest of Bannister Hall on Route 300, is an 18th century brick house, now stuccoed, which was long a tavern.

Bryn Zion Church, a mile northeast of Kenton on Route 300, a brick building now brown-stuccoed, was built in 1771 to serve Welsh settlers of the area. An old cemetery surrounds it.

Prettyman House, at the junction of Routes 300 and 42, was built in 1775; it has good architectural features.

Kenton Hotel, also at the junction of Routes 300 and 42, is a frame building erected in 1809, and long used as a tavern.

"Aspendale," on Route 300 between Kenton and Downs Chapel, is an unusually large Georgian colonial brick house built in 1773, with an older kitchen wing, has never been altered materially and retains all original woodwork and some of the original paint. It is, consequently, of exceptional architectural interest.

Clark House, on a private lane 1½ miles west of Downs Chapel, is an 18th century brick house, later enlarged by frame additions.

CAMDEN AND VICINITY

"Great Geneva," on Lebanon Road near US 113A and built about 1750, is a brick dwelling of architectural interest, carefully restored.

Cooper House, near the north entrance to Camden, was built in 1782. It has notable interior woodwork. Tradition calls it an Underground Railroad Station.

Daniel Mifflin House, opposite the Cooper House, was built about 1796; it too has excellent original woodwork.

Friends Meeting House, Commerce Street, was built in 1805 to serve as a place of worship and as a school for a Meeting organized in 1795.

US 113 and vicinity, south of Camden:

"Wildcat," at the mouth of Tidbury Branch, reached via Lebanon, is a pre-Revolutionary frame house, long the mansion of a prosperous plantation.

Matthew Lowber House, Main Street, Magnolia, was built in 1774; its grounds contain an exceptional pair of "bride and groom" trees which were planted in 1774.

Jehu Reed House, at the junction of the Bowers Beach Road and US 113, is of architectural interest as a demonstration of mid-Victorian grafted on a Georgian (1771) dwelling, the marks of which are especially clear here.

Lowber House, Market Street near Main Street in Frederica, was erected before 1750 and is of architectural interest.

"Mordington," off State Route 12 on a bluff overlooking McColley's Millpond, is an excellent Georgian brick house erected in 1777, with

many distinctive architectural features.

Bonwell House, off Route 12, on Andrew's Lake, is another good 18th century house.

MILFORD

"Parson Thorne" House, 501 West Front Street, built in 1785 by one of the founders of the town, has a number of distinctive structural features. Close by is a family graveyard.

Christ Church, started in 1791, was completed in 1835 and altered to its present condition in 1866. Its cemetery has a number of notable tombs.

Torbert House, at Walnut and Second Streets, was the home of General Alfred T. A. Torbert, a Delawarean distinguished for his Civil War service.

Causey Mansion, the Plaza, South Milford (Sussex County) was built in 1763 by an English architect as the manor house of a large surrounding estate. Despite subsequent alteration, it is of architectural interest; a unit of the brick slave quarters preserved in the garden is a very unusual survival. It has been the home of two Delaware governors.

SUSSEX COUNTY

"Lawrence," on US 13 a mile north of Seaford, is a good example of an early Victorian frame mansion of the area. It was built in 1840.

St. Luke's Church, at King and Poplar Streets in Seaford, was built in 1843 and is the oldest church building in the town.

"Fairview," now the Acorn Club, in Seaford, was an early 19th century country mansion, with distinctive doorways. It was moved here when its original grounds became the site of the Seaford nylon plant.

Collins House, Delaware Avenue, Laurel, is a very old frame house, once the home of Governor Nathaniel Mitchell.

"Cannon Hall," at Woodland, is an early 19th century mansion which was built about 1820.

"Walnut Landing," 5 miles south of Woodland, is a small brick house believed to have been built before 1750, and one of the very few old brick structures in Sussex County.

GEORGETOWN

Original Court House, west side of Bedford Street near the square, was built in 1793 on the site of the present court house, was moved and converted to a dwelling when the newer building was erected in 1837.

The Brick Hotel, on the square at West Market Street, was built in 1836.

"The Judge's," on the southwest corner of Market and Front Streets, was built about 1810, and has been the home of 4 successive eminent judges. The structure, with its matching dependencies, is also of architectural interest.

On the northeast corner of The Square is a house built about 1804, and occupied by Nathaniel Mitchell during his governorship.

Millsborough Furnace, south bank of Millsboro Pond, now in ruins, was built in 1817 and operated until 1879. It was the last surviving furnace of the several which represented an important late 18th and early 19th century industry in Sussex County.

Blackwater Presbyterian Church, 5 miles east of US 113 on Clarksville Road, was built in 1767 to serve a congregation organized in 1667. It retains many original features. Although it has been used only for special services during most of the 20th century, it is of historic and architectural interest.

Fenwick Island Lighthouse, on the State Line in Delaware, was erected in 1857. Near by is one of the few remaining stones placed by the original Provincial survey in 1750-1751.

Fort Saulsbury, at the eastern end of State Route 36, east of Route 14, was a Coast Artillery post during World Wars I and II.

Conwell House, on Route 14 at Broadkill Creek, is of architectural interest as an excellent example of early homes of that area.

Rhodes Shankland House, on Route 14 at Wescoat's Corner, about one mile south of Nassau, was built in 1767.

The Marsh Family cemetery, on a private road about one mile south of Midway, is one of the few family burying grounds, once common in Delaware, still well kept. It is one of the two largest in the State; burials date from 1769.

Lorenzo Dow Martin House, at Christian Street and Scarborough Avenue in Rehoboth, was the farmhouse on the tract sold for development in 1872. It is a good example of the small rural dwellings of Sussex County in the earlier 19th century.

"The Homestead," at Henlopen Acres near Rehoboth, built in 1742, retains all its essential original features and is consequently of substantial architectural interest as one of the oldest houses in the area.

Silver Lake, at the southern limits of Rehoboth, is a State Wildlife Refuge significant as a winter feeding ground for migratory waterfowl.

Coin Beach, near the Indian River Coast Guard Station, is believed, because of the great number of late 18th-century coins that have been found there, to be the locale of the famous wreck of the Faithful Steward in 1785.

LEWES

Zwaanendael Museum, erected in 1931 by the State of Delaware as a tercentenary memorial to the Dutch settlement of 1631, is patterned after a portion of the Town Hall of Hoorn, Holland, the home of David Pietersen de Vries.

David Hall House, on King's Highway opposite Zwaanendael Museum, is one of the best-preserved old houses in Lewes. It was the home of David Hall, Revolutionary leader and a Governor of Delaware.

Lewes Presbyterian Church, King's Highway between Franklin and Washington Streets, built in 1832 with later additions, serves a congregation organized in 1707. Its churchyard contains the graves of many notable residents.

Coleman House, King's Highway north of Madison, date of erection not established, is one of the old dwellings of the town. Near it and once marking its entrance gate, are a pair of "bride and groom" trees, bald cypresses planted in or about 1812.

Hitchens House, King's Highway near Coleman House, is of undetermined but early date. George Whitefield is believed to have preached here in 1739 and 1740, and Francis Asbury at a later period.

Ellis Building, Front Street, NE side of Memorial Park, though dating only from the later nineteenth century, is an interesting relic of earlier shipping practices. A lookout turret and telescope, used from 1884 to 1924 by a ship-brokerage firm to report the arrival and departure of ships, is still in place.

David Rowland House, Front and Bank Streets, built before 1797, was struck during the bombardment in 1813.

St. Peter's Church, 2nd and Market Streets, built in 1858, serves a congregation organized in 1706. Its graveyard has tombs dating from 1707 onward, many of them of prominent Delawareans.

Holt House (has marker).

Daniel Rodney House, 231 2nd Street, was erected about 1800, as the home of Daniel Rodney, who served as Judge and as Governor of Delaware.

Register House, 3rd and Knitting Streets, was erected about 1790. It was the early meeting place of the first Methodist congregation in Lewes.

Orton House, Pilot Town Road near the junction with Ship Carpenter Street, one of the oldest remaining houses, was probably built about 1700.

William Russell House, Pilot Town Road a half-mile from Lewes, built about 1790, retains much of its fine original interior woodwork.

"Fountain of Youth" is an ancient spring known from the earliest days of settlement.

Peter Maull House, opposite the spring, about 3/4 mile from Lewes, a small, shingled white house, was built about 1750. According to legend Jerome Bonaparte and his American bride were entertained here in 1803 when their ship was wrecked off Lewes. At some distance behind this house is the site of an early colonial dike (causeway) across Pagan Creek, and also the site of a very early house, possibly of the Zwaanendael settlement. Both are of arcneological interest.

"Fishers Paradise," Pilot Town Road one mile from Lewes, was built about 1725. It has considerable fine original interior woodwork.

An ancient burial ground, opposite the DeVries Monument, $1\frac{1}{4}$ miles from Lewes, was in use in 1687. Recent investigation indicates that it may be the actual site of the Zwaanendael Fort, and that there are additional sites of archeological interest in the entire area from Lewes to the cemetery plot.

VICINITY OF LEWES

History of Lewes, Delaware, compiled by Virginia Cullen and others, Lewes, 1956, pages 69-78, lists buildings of historical or architectural interest in Lewes and its vicinity. The principal ones in addition to those mentioned in the Guide are:

Marshall House, Dewey Avenue, originally on Pilot Town Road, was erected before 1812.

Three early shingled houses belonging to members of the West family, construction dates uncertain, are located (1) on 4th Street near Savannah Road; (2) on Market Street at "Frog Hill," and (3) opposite (2) above.

Cornelius Burton House, on 4th Street, near Block House Pond site, is another early house.

Chambers House, on Ship Carpenter Street, near 4th, is of especial architectural interest.

Old house with interesting interior detail, on Gills Neck Road, near Savannah Road. Its history is unknown.

Rodney Houses, on Savannah Road, near Front Street, were both parts of a single larger house built about 1776 and later placed on this site. They have several good interior and exterior details.

Ingram House, 2nd Street, near Savannah, is believed to date from before 1750.

Hiram Burton House, 2nd Street, is also believed to date from before 1750.

Hackle-de-Barney, at the juncture of Route 14 and Oyster Rocks Road, now a private dwelling, was once an inn serving the shipping at Oyster Rocks, and also believed to have been an Underground Railroad station.

Benjamin White House on the Oyster Rocks-Milton Road, is an early building, shingled over brick insulating walls.

Hunter House, on an old road from Milton to Cool Spring near the site of Hunter's Mill, is another old dwelling, with brick walls covered by weatherboarding.

Hopkins House, on the Overbrook-Milton Road, has excellent interior woodwork, and is believed to have been built before 1750.

Lewes Common, confirmed to the residents of Sussex County in 1682.

Great Dune at Cape Henlopen, now within the Fort Miles reservation, has been a landmark since the earliest days of settlement. From 1767 to 1926 its summit was the site of Cape Henlopen Light. It is also of geological interest as a remarkably fast-moving formation.

St. George's Chapel, reached by a side road joining Route 24 about $5\frac{1}{2}$ miles from its junction with Route 14, was erected in 1794 to serve a parish organized before 1719. Despite alterations in 1883 it retains many original features.

"White House," on Long Neck Road $3\frac{1}{2}$ miles from its junction with Route 24, was erected in 1722; nearby is an ancient family burying ground. It is one of the very few early brick houses in the region.

"Phillips Hill," 3 miles west of the junction with US 113, is a survival of an early plantation settlement, with colonial shingled house, outbuildings, and quarters intact.

Carey's Campground, on an unnumbered road joining Route 24 at $3\frac{1}{2}$ miles west of US 113, founded before 1830, is one of the few old camp-meeting grounds still in use in the State.

A log corn crib at Mission is a rare survival of the once-standard farm equipment of the area.

Great Pocomoke Swamp, near Gumboro, despite the ravages of fire and drainage, is still of biological and botanical significance.

Bethel M. E. Cemetery, on Line Road, about 2 miles south of its junction with Route 26, has several examples of roofed graves, a once-common burial custom of the area.

Prince George's Chapel, on Route 26, two miles west of Vines Creek, was erected in 1757, replacing an earlier building. Since it remains in very nearly its original condition it is of architectural as well as religious and historical interest.

Christ Church, Broad Creek Hundred, ½ mile off Route 24, about 2 miles east of Laurel, was built in 1771. In almost perfect preservation, and completely unaltered, it is an outstanding example of late colonial church architecture.

Middle Point Markers, near an unnumbered road 5 miles south of Columbia, indicate the southwestern boundary of Delaware as established in 1760 and corrected a few feet by Mason and Dixon in 1768. Both stones are original; the latter, a double crownstone, marks the angle of the Mason-Dixon line.

Hazzard House, Union Street in North Milton, was built about 1790, and was the home of Governor David Hazzard, its builder's son.

Peter Parker House, on Chestnut Street in North Milton, was built about 1835. This, like the Hazzard House, is a well-preserved example of the architecture of its period. It also has an original boxwood garden and a shingled meat-house, the latter an unusual survival of one of the service outbuildings once essential to every substantial home.

Cool Spring Presbyterian Church, 1/3 mile off Route 18 about 7 miles from Lewes, was built in 1855 to serve a congregation formed before 1728. Its churchyard has burials from 1752 onward.

Martin House, reached by a side road joining Route 18 about a half-mile beyond the junction of the road to Cool Spring above, is a small unpainted framedwelling of the late 17th or very early 18th century. It is of especial architectural interest since it represents an earlier building style than most other surviving Sussex County houses.

Collins Millpond, 8 miles west of Georgetown, has bald cypress at the northern limit of their range, and consequently of botanical interest.

SECTION X

GROWTH AND DEVELOPMENT PROJECTIONS

10.01 INTRODUCTION

"The need for water is dependent upon the volume of economic activity within an area and the size of its population."[1] This expression clearly implies that water is a function of these two variables, the economic activity and the population, within a specific area. Further, the statement assumes that sufficient water will be available to meet the need. However, experience has shown that water supply is not unlimited. Hence, as the water need approaches the limit of the supply, the two dependents, economic activity and population, become a function of the supply. The expression can be rewritten: Economic activity within an area and the size of its population are dependent upon the supply of water.

10.02 OFFICE OF BUSINESS ECONOMICS BASE SURVEY

In response to a request from the District Engineer of the U.S. Army Engineer District, Philadelphia, the Office of Business Economics (OBE) of the U.S. Department of Commerce prepared a report entitled "Economic Base Survey"[1] for use in the comprehensive survey of the water resources of the Delaware River Basin.

The report analyzes the economic characteristics, developments, and trends and presents projections of future growth for the Nation and the Delaware area. The basic structural data provided is the framework to be used in assessing future requirements.

The report is the first OBE comprehensive regional evaluation for areas smaller than states but larger than counties. These areas are generally classified as metropolitan areas, or by a geographical designation, and are known as subregions.

We assume that the OBE of necessity worked on the premise that a sufficient supply of water would be available to meet future demands, although the available supply might require legal and physical controls to provide for multiple use.

The projections of population, personal income, etc., are based upon broad economic measures such as gross national product, personal income, number of households, etc. These projections are in no sense intended as forecasts, but merely to provide a meaningful framework within which inquiries involving broad future growth and water requirements may be pursued. The OBE report shows that the growth trend for the country has been at a fairly steady rate, exclusive of cyclical and war periods. National output and income were employed as bench marks.

The OBE states that the economic activities of a region such as the Delaware River Service Area, described later, are influenced fundamentally

by the course of the Nation's overall economy. However, even though the subregions have been influenced by the economy of the region, the subregions have progressed at varying rates with respect to each other and to the national average.

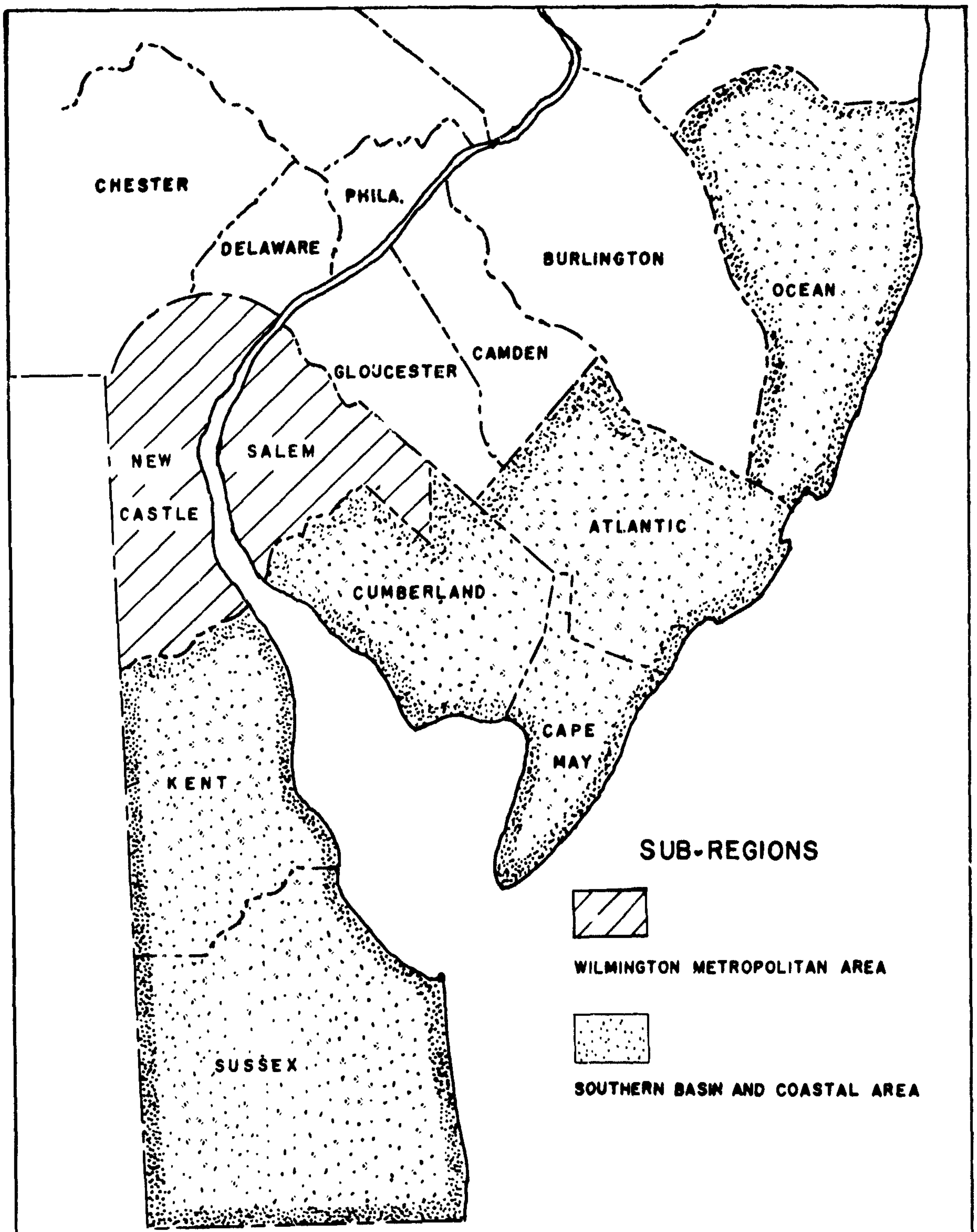
The reported trends for the nation and the region provide a satisfactory basis for appraising the future, however they are not as reliable for the subregions due to the fact that local developments have more impact on the smaller areas--the subregions. The factors of variable population growth, new industrial plants, expansion of transportation facilities, etc., will have a decided effect on development.

The Delaware River Service Area includes 49 counties. After considering the available data and consulting with various private and public officials interested not only in the present survey but also in the much wider uses such classification may have, the Philadelphia District Engineer grouped the 49 counties into 8 subregions. Counties are grouped and, wherever possible, metropolitan areas are designated. The OBE report, according to definition established by the Corps of Engineers, formed the 8 subregions as follows: the New York City Metropolitan Area (Standard Area), New York City Metropolitan Area (Supplement for Expanded Area), Bethlehem-Allentown-Reading Metropolitan Area, Philadelphia Metropolitan Area, Wilmington Metropolitan Area, Upper Basin Area, and the Southern Basin and Coastal Area. The grouping of the various counties into subregions was based upon economic similarity.

The Wilmington Metropolitan Area is composed of New Castle County, Delaware, and Salem County, New Jersey. The Southern Basin and Coastal Area is composed of the counties of Kent and Sussex in Delaware, and the counties of Ocean, Atlantic, Cape May, and Cumberland in New Jersey. These subregions are shown in Exhibit 1.

The projections of the OBE extend to the year 2010, however the years of 1965 and 1980 were selected as convenient intermediate points as they are widely used by other agencies in considering long-term programs. The OBE, in considering longer-term population projections for the United States, parallels long-term developments of the past.

The Census Bureau provided the OBE with alternate projections, based upon different assumptions, designated as Series AA, A, B, and C. Series AA and C correspond to the maximum and minimum projections respectively, however Series A and B fall between the two extremes. The OBE chose to use an intermediate projection which did not correspond with Series AA, A, B, or C. The Bureau of the Census compiled Series V for the OBE to use in making the national projections. A tabulation of these series follows:



STATE OF DELAWARE

INTRASTATE WATER RESOURCES SURVEY

SUB-REGIONS AND COUNTIES

EXHIBIT 1

TABLE 1

UNITED STATES

Projection of Total Population
All Ages of Both Sexes (Millions)

Census Series	1955	1965	1980	2010
V	165	195	248	370
AA	165	193	250	441
A	165	190	241	407
B	165	190	226	307
C	165	186	218	289

From OBE report.

Series V for 2010 is 370 million, which is slightly above the mean for the other four series, which is 361 million.

The OBE, in making projections for the subregions, considered a two-stage approach: 1) What influence will the national pattern have upon the subregions? 2) What share of the national economy will each subregion have at a specified future time? In order to arrive at the latter solution personal income was used as the yardstick to chart the growth of each subregion. Due to certain complexities counties were not considered individually, but were grouped within subregions.

The conclusion must be drawn that all forecasts or projections are estimates of the population level at specified dates. It is realized that the approach is mathematical; in actuality, the numerical values of the populations may occur at earlier or later dates than indicated due to the fact that unforeseen causes may increase or decrease the rate of growth, so the curves may approach and parallel Series AA or Series C. Table 2 lists the projections for the United States, the Delaware River Service Area, and the subregions.

TABLE 2

POPULATION PROJECTIONS
(Thousands)*

	1955	1965	1980	2010	Percent Increase
United States	164,303	195,000	248,000	370,000	125
Delaware River Service Area	21,589	25,000	30,000	42,000	95
New York City Metropolitan	13,851	16,000	18,500	25,000	81
New York City Supplement	1,221	1,500	2,000	3,400	178
Bethlehem-Allentown-Reading	798	900	1,100	1,550	94
Trenton Metropolitan	250	300	400	650	160
Philadelphia Metropolitan	4,121	4,800	5,800	7,900	92
Wilmington Metropolitan	329	450	600	1,000	204
Upper Basin	551	650	750	950	72
Southern Basin and Coastal	469	600	850	1,300	177

* From OBE report.

It is evident from Table 2 that the Wilmington Metropolitan Area will have the greatest rate of change in population of the eight subregions, while the Southern Basin and Coastal Area competes for second place with the New York City Supplemental Area.

Previously it was stated that the OBE provided projections for areas as small as the subregions even though appraisals for these areas would not be as reliable as those of the Basin or the Nation. Consequently, it may be assumed that county projections would be even less reliable.

10.03 POPULATION GROWTH RATES

The information as furnished presented certain difficulties to the State Coordinators. Growth data had to be prepared for State agencies as a basis for their individual State Reports. Consequently it became necessary to issue information applicable to each of the counties, New Castle, Kent, and Sussex. In contrast, the OBE provides a rate of growth for each subregion comprised of the average for several counties, which rate may or may not be true for the county under consideration.

In order to arrive at a basic rate for the period of 1950-1956, reference was made to the statistical tables of population published by the Delaware State Board of Health,[2] which are summarized in Table 3.

TABLE 3

POPULATION ESTIMATIONS FOR THE STATE OF DELAWARE
(Civilian and Military)
(Thousands)

	New Castle County	Kent County	Sussex County	Delaware Total
1950	220.85	38.20	61.95	321.0
1951	225.87	41.63	64.50	332.0
1952	233.43	42.44	66.13	342.0
1953	241.67	44.87	68.45	355.0
1954	248.47	56.16	69.37	374.0
1955	261.91	60.96	73.13	396.0
1956	276.02	64.90	77.08	418.0
1957	289.00	68.60	80.40	438.0
1958	302.40	71.00	84.60	458.0

Based upon Table 3, the average annual percent growth rates calculated for the period of 1950-1958, shown in Table 4 below, are: 4.01 percent for New Castl County, 8.06 percent for Kent County, and 3.92 percent for Sussex County. These rates vary from the OBE rates which are: 4.35 percent for the Wilmington Metropolitan Area, and 2.99 percent for the Southern Basin and Coastal Area for the period 1950-1958. The rate for New Castle County is in harmony with the OBE rate, however the rates for Kent and Sussex County are considerably higher than the OBE rate for the Southern Basin and Coastal Area, indicating that growth in these counties

is above the average for the subregion.

As the period from 1950 to 1965 is now (1959) 60 percent complete, the Delaware Coordinators examined the facts as to the continuation of the current rate into the future. Discussions with various interests in the State indicate that the present rate should continue to 1965. Certain basic factors which have been favorable to the development of industry in New Castle County will continue at least until 1965.

The Delaware Coordinators are unable to concur with the grouping of New Castle and Salem Counties as a unit, since Salem County has not developed similarly to New Castle County. The ratio of population in New Castle County to that of Salem County being 5 to 1, it follows that if the factors influencing the growth of the two counties were the same, Salem County would be developed correspondingly. A study of the recent map published by the U.S. Geological Survey entitled "Wilmington and Vicinity," which includes parts of New Jersey, Delaware, and Pennsylvania, will substantiate that New Castle County has a greater potential land use due to more favorable terrain for drainage, and other factors of interest to industrial and housing developers.

The two counties are not contiguous on the basis of water supply and for various other reasons, primarily existing legislation. State law differs sharply with respect to zoning, water use, and pollution. Delaware's water supply network is already connected with that of Chester County, Pennsylvania. A pipeline across the river to join Delaware water users with those in New Jersey is not only remote but also highly impractical.

Delaware's business experts strongly contend that this portion of the valley will be the major oil refining center of the Nation. This prediction is well under way with the establishment of the new Tidewater plant to receive foreign oil. Port facilities are available at a comparatively small expense in Delaware which are capable of accommodating the largest tankers built. Delaware's Coordinators consider the State's location with regard to interstate highways, railroads, water transportation, etc., as being major factors as generators of development. Based on all these facts, the Coordinators can not realistically visualize a decrease in the rate of growth until 1965.

The rate of growth of Kent and Sussex Counties was above the average for the subregion of the Southern Basin and Coastal Area, and the factors which influence thisshould continue until 1965.

The Delaware Coordinators employed the rates for the period 1950-1958, as developed from the Delaware State Board of Health statistics, as extending to 1965. Beyond 1965 the population projections of the OBE for the Wilmington Metropolitan Area were used to arrive at an average annual percent of growth for the periods of 1965-1980 and 1980-2010. In determining these rates the standard mathematical compounding formula was applied rather than a straight-line projection. The rates obtained for these latter periods were used for New Castle County. In accepting these rates beyond 1965 the State Coordinators are in accord with the OBE report.

The population projections of the OBE were used to determine the average annual percent of growth for the periods 1965-1980 and 1980-2010 for the Southern Basin and Coastal Area, of which Kent and Sussex Counties are a part. These rates were utilized for Sussex County. Kent County, however, due to its geographical position, even though it is included in the Southern Basin and Coastal Area, would be influenced by activities in New Castle County. The exact influence New Castle County exerts is indeterminable. However, in order to adjust the rate, it was assumed 60 percent of the difference in the rates established for New Castle County and Sussex County should be added to the Sussex County rate for the period of 1965-1980 to obtain a rate for Kent County.

For the period 1980-2010 it was assumed that both New Castle and Sussex Counties would influence the Kent County rate, a leveling process occurring, hence the adoption of the average of the rates of the two adjacent counties in establishing the rate for Kent County.

As the OBE report projections terminate at 2010, the Coordinators extended the State projection for population to 2060 for the express purpose of indicating the magnitude of the problem which may develop. The rates for the period 1980-2010 were used for 2010-2060. As the rates from 1980-2010 are lower than the rates for 1958-1965 and 1965-1980, and the rates established for 1965-2010 are based on the Series V projection of the OBE, which is near the arithmetical mean of Series AA, A, B, and C, the rate for 2010-2060 must be considered conservative.

The current rates for Kent and Sussex Counties are higher than the OBE rate for the Southern Basin and Coastal Area. The Coordinators contend the rates established for 1965-2010 are conservative for these areas. For certain reasons the lower counties of Delaware were grouped economically by the OBE, according to definition set forth by the Corps of Engineers, with areas in New Jersey. As Kent and Sussex Counties are above the average rate, we must assume the combined remainder in New Jersey must be of a lower rate.

Kent and Sussex Counties are separated from the remainder of the Southern Basin and Coastal Area subregion by a natural barrier, the Delaware Bay. As a result, the daily intercourse and exchange which normally occurs between counties which are adjacent to each other does not occur, hence Kent and Sussex Counties are not integrated in the economic life of the Southern Basin and Coastal Area. All the counties of Delaware are favored with adjacent lands to the west and to the south, hence they are integrated with the economic life of the Delmarva Peninsula. The growth of Kent and Sussex Counties is influenced by the daily commerce which is maintained among the counties of the Peninsula. The State of Delaware is an integral part of the trade route to the south; this route funnels movements from southern areas to the north, an advantage which does not exist for the Coastal Area of New Jersey.

It is to be noted that after 1965 the rate for Kent County is shown as declining; this reflects an anticipated decline in the military segment of the population now evident in this county.

Based upon the above discussion we consider our rates beyond 2010 to be conservative.

TABLE 4

POPULATION GROWTH RATES

Average Annual Percent Growth Per Period

	New Castle	Kent	Sussex
1958-1965	4.01	8.06	3.92
1965-1980	1.94	2.19	2.35
1980-2010	1.82	1.63	1.43
2010-2060	1.82	1.63	1.43

10.04 POPULATION PROJECTIONS FOR DELAWARE

Using the population established by the State Board of Health for 1955 as a base and applying the average annual percent growth rates as listed in Table 4, and using the standard mathematical compounding formula, the projections are shown in Table 5.

TABLE 5

POPULATION PROJECTIONS BY COUNTIES
(Thousands)

	Actual	Projected				
	1955	1958	1965	1980	2010	2060
New Castle	261.9	302.2	398.1	531.2	912.4	2,248.6
Kent	61.0	71.0	122.2	169.0	274.5	616.3
Sussex	73.1	84.6	110.7	156.5	239.5	487.2
Total	396.0	458.0	631.0	856.7	1,426.4	3,352.1

10.05 PERSONAL INCOME, EMPLOYMENT, PER CAPITA PERSONAL INCOME, AND HOUSEHOLDS

The Office of Business Economics, in preparing their report for the Corps of Engineers also furnished forecasts on personal income, per capita personal income, employment, and number of households projections for the use of the Federal agencies preparing reports.

The Coordinators of the State of Delaware, of necessity, used the data presented in the OBE report to derive ratios which could be applied to the Delaware population projections. Personal income ratios per 1,000 population are listed in Table 6; employment to population ratios are listed in Table 7; and households to population ratios are listed in Table 8.

TABLE 6

PERSONAL INCOME RATIOS

(Billions of 1957 Dollars per 1,000 Population)

Area	1955	1965	1980	2010
Wilmington Metropolitan	0.00304	0.00356	0.00433	0.00700
Southern Basin and Coastal	0.00170	0.00217	0.00271	0.00469

TABLE 7

RATIOS

(Employees to Population)

Area	1955	1965	1980	2010
Wilmington Metropolitan	0.4134	0.4000	0.4000	0.4200
Southern Basin and Coastal	0.4115	0.4000	0.4000	0.4154

TABLE 8

RATIOS

(Households to Population)

Area	1955	1965	1980	2010
Wilmington Metropolitan	0.2857	0.2667	0.2833	0.3000
Southern Basin and Coastal	0.3326	0.3333	0.3294	0.3538

Using the ratios of Tables 6, 7, and 8, and the population projection listed in Table 3, the following Tables, 9, 10, and 11, were submitted to the interested State agencies to assist in preparing their reports.

TABLE 9

PERSONAL INCOME

(Billions of 1957 Dollars)

County	1955	1965	1980	2010
New Castle	0.80	1.42	2.30	6.39
Kent	0.10	0.27	0.46	1.29
Sussex	0.12	0.24	0.42	1.12
Total	1.02	1.93	3.18	8.80

TABLE 10

EMPLOYMENT
(Thousands)

County	1955	1965	1980	2010
New Castle	108.3	159.2	212.5	383.2
Kent	25.1	48.9	67.6	114.0
Sussex	30.1	44.3	62.2	99.5
Total	163.5	252.4	342.7	596.7

TABLE 11

NUMBER OF HOUSEHOLDS
(Thousands)

County	1955	1965	1980	2010
New Castle	74.8	106.2	150.5	273.7
Kent	20.3	40.7	55.7	97.1
Sussex	24.3	36.9	51.6	84.7
Total	119.4	183.8	257.8	455.5

The Delaware Coordinators' projection for percapita personal income for each county varies to a slight degree from the OBE report for the wilmington Metropolitan Area and the Southern Basin and Coastal Area. These projections are shown in Table 12, based on the Coordinators' forecast of total personal income and population for each county.

TABLE 12

PER CAPITA PERSONAL INCOME
(1957 Dollars)

County	1955	1965	1980	2010
New Castle	3,054	3,600	4,300	7,000
Kent	1,639	2,200	2,700	4,700
Sussex	1,641	2,200	2,700	4,700

10.06 EMPLOYMENT PATTERNS AND PERSONAL INCOME BY TYPE

As a guide to interested State agencies and others participating in the State Report, Tables 13 and 14 were furnished as extracts from the OBE report.

TABLE 13

EMPLOYMENT PATTERNS
(Thousands)

	Wilmington Metropolitan Area		Southern Basin and Coastal Area	
	1950	1955	1950	1955
All industries	106	136	161	193
Commodity-producing industries, total	52	68	70	83
Manufacturing, total	39	51	34	39
Food and kindred items	2	2	6	8
Chemicals and kindred items	17	21	2	3
Petroleum and coal	1	NA	-	NA
Primary metal industries	2	2	-	1
Paper and allied industries	1	1	-	-
Noncommodity-producing industries, total	54	69	91	110

NA = Not available.

TABLE 14

PERSONAL INCOME BY TYPE
(Millions of Dollars)

	Wilmington Metropolitan Area		Southern Basin and Coastal Area	
	1950	1955	1950	1955
Personal Income	633	931	582	775
By Type				
Wages and Salaries	398	628	355	503
Other Labor Income	13	27	9	16
Proprietors income	51	57	126	128
Farm	8	5	50	41
Nonfarm	42	52	76	87
Property income	155	200	63	84
Transfer payments	23	32	35	57
Less: Personal contributions for social insurance	6	12	7	12
CIVILIAN EARNINGS 1/	458	701	474	610
By Industry				
Farms	13	11	63	57
Mining	2/	2/	2	3
Contract Construction	37	57	33	49
Manufacturing	217	358	113	143
Wholesale and retail trade	67	96	103	140
Finance, insurance, and real estate	16	25	12	22
Transportation, communications, and public utilities	29	47	35	50
Services	43	66	66	70
Government	25	40	41	68
Other	2/	2/	7	8

1/ Consists of wages and salaries, other labor income, and proprietors' income.

2/ Less than $500,000.00

10.07 CONCLUSIONS

The OBE and the State Coordinators have the same objective, namely to supply projected trends, however the approach toward this objective by each is slightly different. The OBE report states that their analysis is more reliable for the Nation and Delaware Service Area than for the associated subregions due to the fact that local influences will have a greater impact on the economy within a small region. This reasoning can be similarly applied to the counties contained in the subregions, in that projected trends for counties would appear to be less reliable than for the parent subregion.

As the OBE projections are for subregions, each county in the subregion loses its identity. Essentially an average is obtained for the subregion, which may or may not be applicable to the counties contained therein. Due to the averaging process, generalization occurs with regard to the influence of population, land-use, transportation facilities, etc. The procedure may be classified as examining the problems vertically downward toward the foundation.

The State Coordinators' approach is different in that the procedure is to develop the foundation and build upwards, examining in detail every possible influence, and its effects, to establish this foundation. In following this procedure use was made of the mature judgments by the representatives of the various State, County, and Municipal governmental units. This foundation provided the start; however, the coordinators realized as time progressed that other external influences would be exerted on local conditions. Consequently, after laying the foundation, the building material consisted of information developed by the OBE. As a result of this method we consider our forecasts to be firm and conservative.

Special consideration has been given to Kent County. The Delaware statistics indicate the current rate of growth of Kent County is 2.7 times the OBE rate for the subregion. The Coordinators realize that the Dover Air Force Base has been one of the prime factors for this growth. The extent to which this influence will continue is an undetermined factor, however the influence of the Dover Air Force Base may be considered as a catalyst in that it has created a growth of business, demands for public service, and increased housing within the county. However the growth rate for Sussex County, which is distant from the Base, is 1.3 times the OBE rate for the subregion. To the Coordinators this indicates other influences are at work in Kent County besides the Air Base. The conclusion reached is that the present rate calculated by the Coordinators should continue to 1965, after which date the rate becomes substantially lower and the present main influence is eliminated.

The State Coordinators extended the survey to 2060 for the express purpose of determining if the critical period of need for water does not occur by 2010, might it occur before 2060? The results of this decision appear justified by the contents of other reports contained in the State Report.

The forecasts presented are the result of the analysis of present available information, however unforeseen influences will determine if the

predictions prove right for the predetermined dates. If the case proves the predictions are high it should be realized that the predictions will occur at some date beyond the predicted date, and the problems connected with the forecasts will still exist. If the forecasts occur before the specified date the problems created will arrive sooner than expected. Early or late, the problem will occur.

REFERENCES

1. U.S. Department of Commerce, Office of Business Economics; "Report on the Comprehensive Survey of the Delaware River Basin - Appendix B - Economic Base Survey," prepared for the U.S. Army Engineer District, Philadelphia, Corps of Engineers, June 1958, 225 pp.

2. Delaware State Board of Health, Department of Statistics, Dover, Delaware: mimeographed table entitled "Population Estimations for Delaware by County and Race, Civilian and Military (1950-1958)."

SECTION XI

STATE HIGHWAY DEPARTMENT
PLANNING DIVISION

EFFECT OF TRANSPORTATION ON POPULATION GROWTH IN DELAWARE

11.01 GENERAL

The growth of any area depends on a variety of factors such as terrain, climate, water supply, transportation, and other influential forces. The history of transportation in Delaware indicates the role that transportation has played in the development of the State. Industry first settled on the Brandywine River over 150 years ago, not only because of the water supply there for power, but also because water-borne transportation could ship the mill products to their markets. The ensuing spread of settlements soon required adequate transportation by overland routes as well as by water.

a. Present facilities. Over the years the upper part of the State has become a corridor between great metropolitan areas, such as those of Washington and Baltimore, Philadelphia, northern New Jersey and New York City. As a result, the largest movement of goods and people in the State is through this region, taking advantage of two major railroads, major highway connections, and expanding air transport facilities. "Excellent transportation facilities and the central location of Delaware with respect to the most heavily populated area of the country, which is evidenced by the fact that more than 50 million people may be served with Delaware's products within overnight traveling distance, makes Delaware ideal for new plant locations or expansion programs by industry. Its agricultural activities continue to grow and food processing is becoming an important business."[1] These remarks are to be found in several publications of the State Development Department.

b. Industrial development. In line with the historic development and continuing expansion of industrial facilities in New Castle County, considerable industrial growth is also being experienced in the smaller downstate communities, such as Dover, Seaford, Milford, and others. In terms of personal income, manufacturing, trade, and services accounted for 50.8 percent of the total in 1946 compared with 66.9 percent in 1955. Among other factors responsible for this development is obviously the availability of adequate transportation facilities. To quote from "Man's Role in Changing the Face of the Earth," by Thomas et al., "Few forces have been more influential in modifying the earth than transportation, yet transportation itself is the result of other forces."[2]

11.02 ECONOMIC EFFECT OF TRANSPORTATION IMPROVEMENTS

The economic effect of improved highway transportation has been clearly substantiated in studies made in various parts of the United States. For example, Route 128, the circumferential route around Boston, Massachusetts, is being developed as a limited access 4- and 6-lane highway on new

location in the nearest fringe of undeveloped land adjacent to the suburbs. Two unforeseen things happened when sections of the road were opened. First, about three times as much traffic appeared as was forecast; second, there was a rapid growth of industrial plants along the highway. An actual count shows that 65 new industries located there within the past few years. Articles relating to the spectacular industrial growth that has taken place along Route 128 can be found in several publications.[3]

a. Industrial and commercial effects. In Texas, extensive studies into land value changes were made in connection with the Houston-Gulf Freeway.[4] In this case one objective of the study was to determine changes over several years in the market value of properties in areas presumably affected by the freeway and of those in nonaffected areas. Growth four times that of the nonaffected areas was found in many areas influenced by the freeway construction. Many similar studies have been conducted in California by the California Division of Highways concerning the effect of freeway and controlled-access highway construction on adjacent lands.[5] In practically all cases, particularly those involving freeway construction in or near a metropolitan area, the industrial growth and commercial growth have been beyond expectations.

b. Residential development. Another example of freeway influence is cited in the booklet "What Freeways Mean to Your City."[6] In one case a community has been developed as a planned city about 18 miles from Los Angeles City Hall. Driving time for this distance is about 25 minutes. According to the developer of the project, "In two years La Mirada has acquired a population of 50,000 largely because the Santa Ana Freeway and connecting fast arterials make it possible for the population to go to and from work easily." A similar case is that of the Sunkist Gardens development about 20 miles from downtown Los Angeles. The developer reported that "Building of the San Bernardino Freeway, even in partially completed form, caused sales to boom in Sunkist Gardens, where in 2 years we sold nearly 2,000 homes valued at more than $19,000,000."

c. Rural benefits. An obvious third benefit of improved highway facilities is that faster transportation of goods and services can be achieved to and from agricultural regions. Farm products can be distributed to a broader market in less time and costs of transportation are reduced. Trips from Dover to New York, for example, which might have been made several years ago in about 6 hours by truck, can be made now within a period of 3 hours. This fact alone serves to emphasize the value of Delaware's agricultural land in supplying the demands of the large metropolitan areas for food products.

11.03 FORESEEABLE HIGHWAY IMPROVEMENTS

The next few years will see many improvements on a regional basis to the highway transport system. The improvements in Delaware and the surrounding states will all have their effect on the future development of this region.

a. Short term improvements. Improvements which will come about in the near future will include, as shown on the map of "Delaware and Regional Highways," the interstate highway system in the northern part of the State, which will include another crossing of the Delaware River near the

present bridge, a connection from the interstate system in Delaware to the Chesapeake Bay Bridge in Maryland, and further construction of controlled access highways within the entire State of Delaware. There is the relatively near prospect of improved crossing facilities of the Chesapeake Bay at Norfolk, Virginia, which will in itself generate considerable traffic through the Peninsula. There is also the possibility of a ferry crossing on the lower Delaware Bay between Lewes and Cape May in New Jersey. The construction of additional miles of divided highway on US 113 in Kent County is under way or scheduled for the near future.[7] All the improvements mentioned above are currently under construction or in the planning stage and will be in use within the next 15 years.

b. Long term improvements. Longer range highway improvements will call for construction, on new location, of new north-south highways paralleling the present US 13 in order to provide adequate north-south traffic service for our expanding population. Other probabilities in the distant future are improved east-west highways of the freeway type on new locations in the southern portions of the State. The net result of all these highway improvements will be first, to connect the coastal resort areas of Delaware with the population centers of Baltimore, Washington, and Philadelphia; second, to provide rapid access to and from these metropolitan areas for agricultural producers in the Delmarva Peninsula; and third, to provide efficient highway service for local residents.

11.04 EFFECT OF HIGHWAY IMPROVEMENTS LOCALLY

The highway improvements mentioned above will result partly from the pressure of increased population, which will demand adequate highway transportation in order to maintain satisfactory economic conditions in the State. But at the same time the improved highways will serve as a stimulus to further development of the State's economic welfare.

a. Short term effects. In the Wilmington area the effect of the interstate system on the growth of suburban developments has already been felt, even though none of the interstate system is yet opened to traffic. For example, in the vicinity of one interchange on the route, a development of 1,200 homes is being constructed. The proposed Chesapeake Bay Bridge connection will pass through an area at present largely agricultural. But the fact that this highway will connect with the interstate system means that travel time from the vicinity of Middletown to Wilmington will be reduced considerably. As a result, the area between Middletown and the interstate freeway may well show a population growth which would otherwise be deferred or not occur. This growth will result from the introduction of new residential communities, from new industries which will also be served by the Pennsylvania Railroad, and from services connected with highway travel and tourist business. The fact that the district served by this proposed highway is within a 10-mile radius of the Tidewater Refinery makes its rapid development even more likely since satellite industries will presumably develop around this petroleum products center.

The future impact of some of these highway proposals has been anticipated by the Regional Planning Commission of New Castle County in their master plan and proposed zoning arrangements.[8] The plan envisages considerable industrial growth in the Newark area, in the vicinity of the Dela-

aware Memorial Bridge, and in the vicinity of the Delaware City refinery.

b. Long term effect. The major improvements of providing additional parallel routes to our existing highways will have the effect of making the entire Delmarva Peninsula more accessible to surrounding areas. It will increase the value of this area as a farming, industrial, and distributional center. The highways will further increase the popularity of the resort areas along the Atlantic Ocean and the Delaware Bay, and thus will contribute to the expansion of tourist facilities along the coast line. The anticipated expansion of Delaware's resort facilities is indicated in another section of this report.

Increasing industrial concentrations in the upper New Castle County area, as well as those which will undoubtedly develop around the municipal centers in the lower part of the State, obviously mean an increased demand for labor, increased construction, and finally, an increased population. This trend will develop still further in the downstate area as highway facilities and other requirements for industry are improved. There is no reason to believe that the experiences found in other parts of the country, some of which were outlined previously on the effect of major highway improvements, will not be duplicated in Delaware as the transportation network is improved.

11.05 SUMMARY

In conclusion, better highways offer great direct benefits to industry as well as to services dependent on travel. With respect to industry, highway improvements make it easier and more economical to bring in raw materials and to ship out finished products. Improved highway transportation means that employees of industry can be provided efficient, safe transportation to and from their jobs. These are major factors to an industrial concern. The invitation extended to industry through improved highway facilities obviously invites more workers and more families into the area of influence. The same is true with respect to commercial and highway service interests.

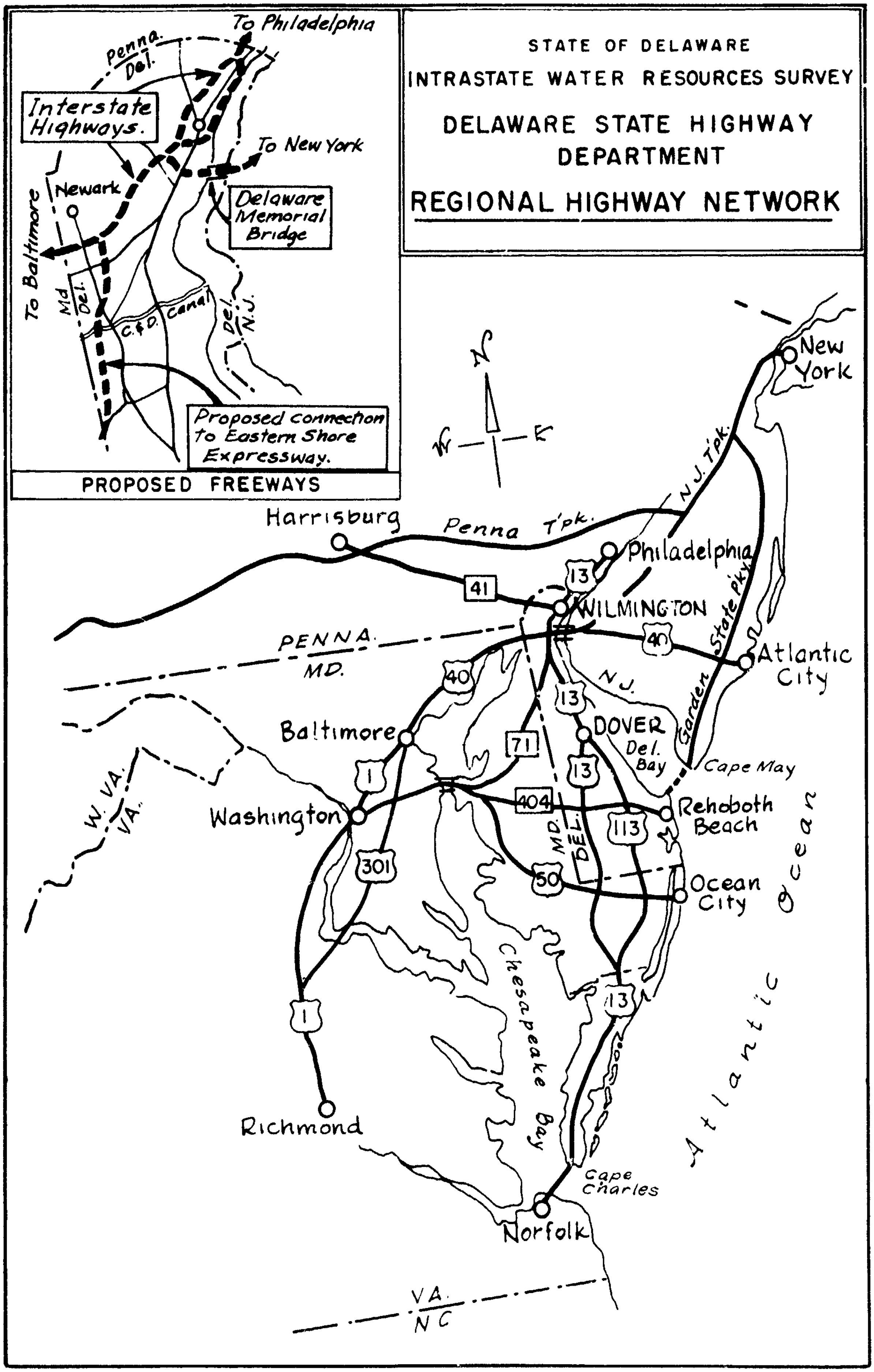
Delaware's highways play their part, as do other aspects of the State's responsibilities to its citizens, in sustaining Delaware's economic health. The major improvements which are being planned today and which can be foreseen in the future are designed to make a significant contribution in this regard. Improved connections between production and market areas, within and outside the State, facilities for tourist travel, and accessibility for workers all promote increased personal income and expansion in all phases of economic life. Other natural and manmade resources must be preserved and supplemented to maintain the growth which is already evident and which can only be accelerated by the improved highways which belong in Delaware's future.

(Note: Superscript numbers 1 through 8 appearing in the text refer to the bibliography on page 11-6.)

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE STATE HIGHWAY DEPARTMENT

REGIONAL HIGHWAY NETWORK



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SECTION XII

UNEMPLOYMENT COMPENSATION COMMISSION

WITH THE ESTABLISHMENT OF NEW INDUSTRIES IN THE STATE WHAT WILL BE THE AVAILABILITY OF LABOR IN THE FUTURE?

12.01 GENERAL

The composition of the United States labor force has experienced a number of changes in recent years. The proportion of younger workers has declined; the number and proportion of older workers have risen despite a tendency for earlier retirement. A most dramatic change has been the tremendous increase in the number and proportion of women workers. An equally dramatic change has been the tremendous increase in the number of part-time workers (persons working between 1 and 34 hours per week). Between 1947 and 1956 the number of part-time workers increased by more than 3 million, a gain of 40 percent, compared with less than 10 percent for full-time workers. Most of the increase in part-time workers has come from women and young people.

a. Effect of war. During the past two world wars the demand for labor of all types and skills rose sharply. During those periods of crisis the total civilian labor force was able to expand to unprecedented proportions. The number of women in the work force increased along with an increase in young and older workers.

b. Effect of technology. In the past, because of technological changes and changes fostered in the industrial composition of the work force, there were periods of short-term labor scarcity. In the long run, however, the demand for labor has generally been met and any sharp change in the future in the demand for workers of certain skills and training may not be met in the short run, but adjustments will be made rapidly.

12.02 TRENDS

With the changes that will come in 50 and 100 years it would be presumptuous to draw any positive conclusions. However, the following tendencies of the last few decades might be pointed out to throw some light in the industrial composition of our society in the future. The proportion of farm labor to the total population has been declining at a fairly rapid rate. The importance of manufacturing has dropped. Service industries of all kinds have expanded rapidly along with the services provided by federal, state, and local government, particularly in the areas of education, health, and welfare.

a. Skills and training. The skills and training needed by our diversified industrial society have been increasing. Workers entering the labor market will continue to have increasing years of schooling and particular skills that will not be easily transferred to other

industries. The age distribution of the labor force has continued to become older as entry into the labor market occurs at an older age because of more years spent in school and the increasing life span of the population in spite of earlier retirements. The proportion of women in the work force has increased but this continued increase will depend upon economic and social factors that are subject to rapid change.

b. Availability of labor. The availability of labor is dependent upon numerous factors. Some of these factors are the type of industry in the market for labor, the skills required by the industry, and the effect that automation may have upon industry.

c. Automation. We must consider the effects of automation upon the labor force. There is a widespread feeling that automation will bring many changes in our economic and social structure. The potential impact upon employment requirements, hours of work, and work skill has aroused particular concern. Some of the experts have cited instances of actual or feared displacement of workers while others have forseen possible shortages of certain classes of workers resulting from automation.

(1) Automation affects the division of labor, not the numbers. To place automation in its proper perspective it should be viewed as a specialised aspect of technological change. In the past the net effect of technological change upon employment has been to redistribute occupational employment. For example, employment is at high levels despite the technological progress of the past 50 years. During this period, however, there were significant changes in the pattern of job opportunities. There have been continuing trends toward relatively greater numbers of professional and clerical workers and operatives. At the same time substantial declines have occurred in the employment of laborers.

(2) Significance of automation. It is safe to conclude that so far the overall impact of automation on occupational structures has not been great. The significance of the changes which have occurred is merely in their implications for future changes when automation is more extensively applied in industry.

d. Effects of automation on the work week. It is believed that because of automation, population increases, and social changes, the work week will be shortened. In the next 50 years such a change may not be too significant, but by the year 2060 the work week may well be less than 30 hours per week. The hours of work, however, will be geared to the economic structure, the military need, and to technological changes and may at one point be much greater than at another.

12.03 CONCLUSION

It is our assumption that, based on population estimates submitted for the years 2010 and 2060, the labor force required for the year 2010 would be approximately 42 percent of the total population, or 597,000. By the year 2060, however, only 40 percent of the total population would be utilized in the labor force. This conclusion is based

upon the assumption that young persons will not enter the labor force until a later age as schooling required will be much more extensive than at present and the probability that the age of retirement, even with an increase in the life span, will be at an earlier age.

The labor force has become very flexible to meet changing demands. During times of stress there has been a labor reservoir available of women, young persons, and the older retired workers. It is our belief that this pool will always be available to draw upon. However, the skills required may not, on short notice, be at hand. If time is of no consequence, this shortage of skill can be eliminated within a relatively short time by industrial training techniques.

SECTION XIII

DELAWARE CHAMBER OF COMMERCE

13.01 GENERAL

Other sections of this report describe various aspects of the circumstances and forces at work which will tend to increase the population of Delaware. It is estimated that new industries have given employment to 30,000 persons in the state since 1934. But the older industries must not be overlooked. As the population increases the older industries expand and grow, offering their well-known services and products to the larger market and, at the same time, employing more workers. In many instances the older firms have been more stable than the new ones.

13.02 EFFECTS OF INDUSTRY UPON COMMUNITY GROWTH

It has been estimated that for each 100 industrial payroll jobs created, employment is afforded 6 other wage earners in retail and service establishments. This is an indication, therefore, that the primary payrolls of industry are the motivating factor in population growth.

a. Collateral growth. When industry moves into an area there is a natural increase in the demand for all types of services such as wholesale and retail, all forms of transportation, electric power, gas, sewerage, and water. The supplying of these services generates additional payrolls and consequently is a contributing factor to population growth.

(1) Northern Delaware. The growth of New Castle County is somewhat assured, the only limiting factor in this particular county being the availability of land and proper land use. Land use is now controlled by a county-wide Zoning Code, which, although comparatively recently enacted, has already shown beneficial effects on land use. New Castle County's growth can be mainly attributed to its geographic position and the excellent transportation facilities afforded by rail, water, highway, and air. These services naturally follow closely the creation of industry in the County and at the same time the industrial growth was made possible by the fact that in New Castle County railheads were able to reach the waterfront.

(2) Southern Delaware. The same situation does not exist in Kent and Sussex Counties. It is to be noted that at no point between Delaware City and Lewes does the railroad reach the waterfront, and this has probably been the chief contributing factor to the lack of industrial development in those two counties. It has been proposed that the State of Delaware initiate State ports in both Kent and Sussex Counties with authority to bring railheads to the waterfront, acquire acreage at logical locations and offer them for lease to industry. If this were done the indus-

trial picture of Kent and Sussex Counties would change materially and would no doubt mean the location of a large number of industries desiring to take advantage of combined rail and water transportation and the availability of water for manufacturing purposes.

13.03 POPULATION GENERATORS

a. Industrial development. During the past 50 years the character of industry in Delaware has changed considerably and will no doubt continue this change for many years to come due to technological advancements. From a period of a few industries engaged in but a few lines of manufacture, industry in Delaware now presents a well-diversified picture which is highly desirable for general economic stability. During recent years a better balance between factory workers and office workers has been brought into being. There is no question that existing industries will have a powerful influence on future population growth so long as the business climate, legislatively speaking, continues to be good.

b. Transportation changes. During recent years we have seen the steady diminution of rail transportation since the introduction of the trucking industry. There are no indications that this trend will not continue as long as Delaware and the other states provide the highway system upon which trucks operate. Accelerated steps toward enlarging the highway systems are now being taken through the construction of limited access highways. While the number of people employed by the trucking industry is higher on a tons-per-mile basis, the cost of operation is less because of a much lower capital investment. At present we do not see any reversal in this trend, although the railroads will still have to haul heavy tonnages within the state.

c. Power sources. Presumably the safe and economic development of nuclear energy will tend to equalize the cost of generating electricity throughout the world, and where this cost is a fundamental factor in determining industrial locations, it will tend to eliminate the necessity of being close to sources of fossil fuels or hydroelectric plants as determinative factors in selecting plant sites. Thus power sources may be constructed closer to centers of use than ever before, which is of definite advantage to Delaware because there is no feasible hydroelectric development site or possibility in Delaware or the Delmarva Peninsula.

13.04 FLOOD CONTROL PROBLEMS

Insofar as the Delaware River itself is concerned in Delaware the problem of flood control is nonexistent. However, certain tributaries of the River, such as the Brandywine, Christina, Red Clay, and White Clay, do offer some flood hazard. At this time no recommendations are offered for the establishment of flood warning systems other than those now in effect by the Weather Bureau, which has a warning station in Philadelphia, insofar as the Brandywine is concerned. Some industries on the Brandywine have established their own warning systems which are proving to be adequate.

SECTION XIV

CIVIL ENGINEERING DEPARTMENT
UNIVERSITY OF DELAWARE

SURFACE WATER SUPPLIES OF NORTHERN DELAWARE

14.01 OBJECT AND SCOPE OF REPORT

The object of this report is to determine the magnitudes of surface water supplies of Northern Delaware, the 280-square-mile land area of New Castle County north of the Chesapeake and Delaware Canal. Exhibits 1 and 2 show the major streams and their drainage areas.

14.02 AVAILABLE RECORDS

Records of precipitation and runoff for the major streams draining Northern Delaware were analyzed to determine long-term mean values, trends, frequency of low flows, and required storages for given rates of drafts. A tabulation of the records used in the analysis is given below:

a. Precipitation records.

Table 1

Station	Year of Record
City Hall, Wilmington, Delaware	1894-1911
Porter Reservoir, Wilmington, Delaware	1912-1947
New Castle County Airport, Wilmington, Delaware	1949-1957

b. Runoff records.

Table 2

Stream and Station	Drainage Area (sq mi)	Year of Record
Brandywine at Chadds Ford, Pa.	287	1912-1955
Brandywine at Wilmington	314	1947-1955
Christina at Cooch's Bridge	20.5	1943-1955
White Clay above Newark	66.7	1952-1955
White Clay near Newark	87.8	1932-35 & 1943-55
Red Clay at Wooddale	47.0	1943-1955
Shellpot Creek at Wilmington	7.46	1946-1955

14.03 PROCEDURE

Cumulative rainfall and runoff records were plotted. Average low flows for consecutive days (7, 15, 30, 60, 120, 183, 274, 365) by years were extracted from the runoff records. These values were arrayed, assigned plotting positions (according to $m/(n+1)$, where m = order number and n = number of years of record), and plotted on log probability paper. Low flow discharges were obtained from the trend lines established from the plotted points for recurrence intervals of 2, 5, 10, 25, and 50 years. These values, based upon relatively short records, were adjusted to the 44-year

base record which includes the droughts of the early 1930's and excludes the 1910 drought. The 1912-1955 record of the Brandywine at Chadds Ford was used instead of longer records from more distant streams to avoid regional extrapolation of stream flow data.

Required storages for various drafts during low flows of recurrence intervals ranging from 2 to 50 years were obtained from plots of storage-draft-frequency curves. The required storage for a given draft is the maximum difference between the cumulative draft and the cumulative available flow curves (found graphically from the plots).

14.04 FINDINGS

The findings of the report concerning surface water supplies in Northern Delaware are concisely summarized in Tables 3, 4, and 5, and in Exhibits 7, 8, 9, 10, and 11. Supporting analyses, tables, and exhibits are in subsection 14.05. Information concerning aspects peripheral to the report's subject (such as geology, population, water consumption, climate, and water quality, etc.) can be found in references 1 and 2.

a. Natural average low flows. Table 3 lists natural average low flows of varying durations (7 to 365 days) for recurrence intervals of 2 to 50 years for the principal streams of Northern Delaware, namely the Brandywine, Christina, White Clay, Red Clay, and Shellpot. Values given in units of rate of flow per unit area (mgd/sq mi) are easily converted to rate of flow (mgd) for any points along the streams. The values in Table 3 have been adjusted to the 44-year base period 1912-1955.

b. Allowable drafts for various storages. Table 4 gives values of allowable drafts for various amounts of storages (10 mg/sq mi to 300 mg/sq mi) during low flows of recurrence intervals from 2 to 50 years for the 5 principal streams in Northern Delaware. Table 4 is useful for determining safe yields developed by proposed reservoirs. Table 4, based on Table 3, relates draft and storage to recurrence intervals and thus supplies more information than the usual analysis based upon the Ripple Method, which bases safe yield upon the worst drought on record.

c. Safe yields for 3 proposed stream storage projects. Table 5 presents information on safe yields for the 3 proposed stream storage projects[3] (Corps of Engineers) on the Brandywine, White Clay, and Christina streams. Values in Table 5 are based on the condition that all the listed storages are available for draft. Assuming all listed storages are available for draft, the combined safe yield (for 25-year recurrence interval) from the 3 proposed reservoirs is:

for minimum development 308 mgd
for maximum development 480 mgd

d. Safe yields with 25% allowance for unavailable storage. A more realistic approach would make allowance for unavailable storage caused by such factors as seepage, evaporation, silting, head requirements, etc. Assuming 25% of the total storage for each proposed reservoir is unavailable for draft, the safe yields for the 25-year recurrence interval are listed below.

TABLE 3

FREQUENCY OF LOW FLOWS OF STREAMS IN NORTHERN DELAWARE

STREAM GAGING STATION YEARS OF RECORD	AREA Sq. Mi.	RECUR. INTER. Years	AVERAGE FLOW* FOR LENGTH OF CONSECUTIVE DAYS Million Gallons per day per Square Mile. 7 DAY	15 DAY	30 DAY	60 DAY	120 DAY	183 DAY	274 DAY	365 DAY
BRANDYWINE CREEK		2	.261	.282	.306	.358	.438	.570	.700	.856
AT CHADDS FORD		5	.187	.200	.218	.252	.314	.372	.500	.680
	287.0	10	.153	.167	.182	.210	.250	.304	.410	.585
1912-55 INCL.		25	.126	.135	.149	.171	.203	.241	.340	.497
		50	.110	.120	.129	.150	.178	.209	.295	.447
WHITE CLAY CREEK		2	.255	.267	.287	.330	.416	.478	.606	.714
NEAR NEWARK		5	.152	.174	.190	.221	.297	.372	.476	.575
	87.8	10	.105	.124	.137	.173	.241	.306	.370	.498
1932-35, 1943-55		25	.069	.084	.098	.127	.186	.247	.328	.413
INCL.		50	.051	.065	.079	.103	.155	.195	.277	.360
RED CLAY CREEK		2	.266	.308	.336	.360	.438	.533	.634	.752
AT WOODDALE		5	.176	.207	.227	.236	.321	.388	.488	.584
	47.0	10	.131	.156	.176	.193	.260	.311	.372	.486
1943-55 INCL.		25	.087	.112	.128	.153	.205	.238	.313	.377
		50	.066	.087	.103	.129	.172	.194	.262	.317
CHRISTINA RIVER		2	.128	.144	.174	.216	.253	.362	.581	.690
AT COOCHS BRIDGE		5	.084	.103	.128	.165	.198	.266	.405	.540
	20.5	10	.061	.079	.101	.133	.160	.210	.279	.450
1943-55 INCL.		25	.042	.060	.074	.096	.119	.154	.225	.360
		50	.030	.043	.054	.080	.100	.121	.182	.300
SHELLPOT CREEK		2	.052	.063	.079	.107	.177	.326	.550	.713
AT WILMINGTON		5	.037	.043	.054	.082	.142	.220	.346	.500
	7.46	10	.031	.036	.044	.070	.123	.167	.255	.412
1946-55 INCL.		25	.026	.029	.034	.058	.100	.131	.177	.323
		50	.022	.025	.029	.051	.086	.110	.135	.279

*Values in Table are adjusted to 44-year record at Brandywine Creek, Chadds Ford. 1912-1955 Inclusive

TABLE 4

REQUIRED STORAGE vs. ALLOWABLE DRAFT vs. RECURRENCE INTERVAL FOR STREAMS OF NORTHERN DELAWARE

GAGING STATIONS	DRAIN. AREA Sq Mi	RECUR. INTER. YEARS	NATURAL 7-DAY FLOW MGD/SM	ALLOWABLE DRAFT (mgd/sm) FOR THE AMOUNT OF STORAGE UNCORRECTED FOR SEEPAGE AND EVAPORATION								
				10 mgsm	25 mgsm	50 mgsm	75 mgsm	100 mgsm	150 mgsm	200 mgsm	250 mgsm	300 mgsm
BRANDYWINE CREEK	287	2	.261	.500	.637	.820	.970	1.087	1.277	1.420	1.540	1.646
at Chadds Ford	287	5	.187	.397	.497	.640	.767	.875	1.060	1.220	1.360	1.496
1912-1955 incl.	287	10	.153	.325	.420	.557	.676	.780	.960	1.120	1.263	1.400
	287	25	.126	.268	.370	.500	.616	.720	.896	1.050	1.190	1.320
	287	50	.110	.240	.325	.450	.563	.662	.840	.990	1.130	1.262
WHITE CLAY CREEK	87.8	2	.255	.477	.590	.745	.870	.970	1.130	1.250	1.352	1.440
near Newark	87.8	5	.152	.378	.481	.628	.748	.845	1.010	1.141	1.240	1.363
1932-35 and	87.8	10	.105	.342	.427	.547	.650	.740	.900	1.037	1.160	1.280
1943-55 incl.	87.8	25	.069	.270	.380	.500	.602	.692	.853	.990	1.117	1.235
	87.8	50	.051	.233	.230	.425	.550	.638	.787	.920	1.036	1.146
RED CLAY CREEK	47.0	2	.266	.517	.630	.787	.910	1.010	1.100	1.250	1.330	1.386
at Wooddale	47.0	5	.176	.390	.500	.643	.760	.860	.955	1.123	1.221	1.300
19[illegible]-55 incl.	47.0	10	.131	.315	.410	.541	.653	.747	.842	1.022	1.130	1.223
	47.0	25	.087	.276	.370	.500	.610	.700	.800	.985	1.098	1.198
	47.0	50	.066	.228	.315	.444	.545	.647	.745	.940	1.055	1.160
CHRISTINA RIVER	20.5	2	.128	.340	.450	.630	.790	.926	1.140	1.300	1.436	1.600
at Coochs Bridge	20.5	5	.084	.290	.380	.530	.658	.763	.950	1.106	1.250	1.430
1943-55 incl.	20.5	10	.061	.240	.330	.462	.565	.660	.830	.984	1.130	1.322
	20.5	25	.042	.200	.285	.404	.502	.598	.760	.904	1.040	1.220
	20.5	50	.030	.180	.253	.365	.462	.450	.708	.845	.973	1.142
SHELLPOT CREEK	7.46	2	.052	.262	.400	.585	.740	.870	1.092	1.270	1.417	1.545
at Wilmington	7.46	5	.037	.223	.337	.490	.620	.730	.916	1.064	1.200	1.320
1946-55 incl.	7.46	10	.031	.204	.300	.430	.540	.637	.802	.948	1.077	1.200
	7.46	25	.026	.177	.250	.360	.460	.550	.719	.865	1.006	1.142
	7.46	50	.022	.144	.212	.320	.412	.500	.662	.808	.945	1.080

TABLE 5

SAFE YIELDS OF CORPS OF ENGINEERS PROPOSED STREAM STORAGE PROJECTS
ON THE BRANDYWINE, CHRISTINA, AND WHITE CLAY STREAMS

No.	STREAM	STORAGE*		Elev.	ALLOWABLE DRAFT** FOR STATED RECURRENCE INTERVALS									
					2 Years		5 Years		10 Years		25 Years		50 Years	
		Acre-Ft.	mg/sm	Ft.	mgd/sm	mgd	mgd/sm	mgd	mgd/sm	mgd	mgd/sm	mgd	mgd/sm	mgd
6	BRANDYWINE	96,000	102.6	202	1.10	336.6	0.88	268.8	0.79	241.4	0.73	223.8	0.67	205.2
	306 sq mi	206,000	220.0	222	1.47	450.0	1.28	391.8	1.18	360.8	1.11	349.6	1.05	321.0
5	CHRISTINA	17,000	138.0	40	1.09	44.6	0.91	37.3	0.79	32.4	0.72	29.5	0.67	27.5
	41 sq mi	40,000	318.0	50	1.59	65.2	1.43	58.6	1.32	54.1	1.22	50.0	1.14	46.7
[illegible]	WHITE CLAY	27,600	133.0	149	1.08	73.4	0.96	65.3	0.85	57.8	0.80	54.4	0.74	50.4
	68 sq mi	57,600	278.0	175	1.40	95.2	1.32	89.8	1.23	83.6	1.18	80.2	1.10	74.8

* Storage for evaporation, seepage, silting, etc., should be subtracted from the listed figures to obtain available storage.

** Available draft figures in table are based upon all of listed storage being available.

TABLE 6

25-year safe yields for the Corps of Engineers' proposed storage projects for the Brandywine, Christina, and White Clay Streams (25% of the total storage is unavailable).

No.	Storage Projects	Range of Development	Safe Yield for 25-Year Recurrence Interval (mgd)
(6)	Brandywine	minimum	190
		maximum	290
(5)	Christina	minimum	25
		maximum	43
(8)	White Clay	minimum	47
		maximum	69
Combined Brandywine, Christina, White Clay		minimum	272
		maximum	402

If the 3 proposed reservoirs become reality, the combined safe yields (for the 25-year recurrence interval) would range between 272 and 402 mgd depending upon the degree of development.

e. Cumulative and mean annual rainfall. Plots of cumulative rainfall for the years of record show a fairly consistent trend with an overall mean annual rainfall of 44.47 inches. By decades the mean annual rainfall is tabulated below:

TABLE 7

Mean Annual Rainfall by Decades Over Northern Delaware

Decades	Mean Annual Rainfall (inches)
1894-1899	42.87
1900's	44.76
1910's	45.42
1920's	44.52
1930's	46.02
1940's	44.44
1950-1957	42.20

f. Cumulative and mean runoff. Plots of cumulative runoff for the gaged streams also exhibit a consistent trend until about June 1953, when a noticeable drop in runoff rate occurs for all gaged streams. This reduced runoff rate continues up to the most-recently available records, October 1956. The following tabulation lists the mean runoff rates for the gaged streams:

TABLE 8

Mean Runoff Rates for Streams
of Northern Delaware

Stream	Years	Mean Mgd/Sq Mi	Years	Mean Mgd/Sq Mi
Brandywine at Chadds Ford, Pa.	10/31-9/53	1.41	6/53-10/56	---
Brandywine at Wilmington	12/46-9/56	1.47	6/53-10/56	1.31
White Clay near Newark	10/31-9/36 6/43-9/56	1.25	6/53-10/56	1.10
White Clay above Newark	3/52-9/56	1.20	6/53-10/56	1.10
Christina at Cooch's Bridge	4/43-9/56	1.27	6/53-10/56	1.12
Red Clay at Wooddale	4/43-9/56	1.35	6/53-10/56	1.18

(Supplemental and supporting information is presented in the Appendix.)

14.05 APPENDIX

a. Streams of Northern Delaware. Exhibit 1 shows the Christina-Brandywine drainage systems, main tributaries, and the location of the rain and stream gaging stations in Northern Delaware. The headwaters of these streams are situated in the Piedmont Plateau mostly outside of the State of Delaware. These streams drain through the Coastal Plains to the Delaware River.

b. Drainage areas of streams in Northern Delaware. Exhibit 2 shows clearly that most (85%) of the watershed area of the streams draining into Northern Delaware lies outside of Delaware. Of the drainage areas shown, only the relatively small Shellpot Creek lies wholly within Delaware. Because of the interstate nature of these streams, interstate agreements on the distribution of these waters becomes increasingly important to Delaware as the need for water increases.

c. Mean annual rainfall and runoff. Exhibit 3 shows a plot of mean annual rainfall and runoff. The ultimate source of surface water is the precipitation which falls within the watershed. For Northern Delaware the mean annual precipitation is 44.47 inches according to the Wilmington record of 1894-1957. Runoff records for gaging points on the local streams are relatively short. Based upon these records the mean annual runoff of the five streams are: Brandywine 19.10 inches; White Clay 17.05 inches; Red Clay 18.05 inches; Christina 17.14 inches; and Shellpot 17.85 inches.

d. Mass rainfall and runoff. The temporal variations of rainfall and runoff is shown in Exhibit 4. The slopes of the lines represent the long term averages. It can be seen that the trends of precipitation are relatively constant although the last three years of record (1953, 1954, 1955) are about 11 percent below the record means.

e. Runoff-precipitation ratio. A plot of the ratio of runoff to precipitation, Exhibit 5, shows that the ratio varies from about 0.26 to 0.60. The means of the runoff/precipitation ratio for the four streams are: Brandywine 0.43, White Clay 0.38, Red Clay 0.41, Christina 0.38. This ratio varies from year to year.

f. Discharge-draft-storage relationships. Although mean annual figures are important for determining long term trends, of primary importance for surface water supply are the low flow characteristics. Statistical studies such as described in the main body of the report allow the construction of plots similar to Exhibit 6. The lower curve, total discharge available, is plotted through points whose ordinates are the product of mgd/ sm x no. of days. The various lines radiating from the origin denote drafts of differing magnitudes. Storage required is the maximum vertical distance between the draft and total discharge-available lines. Its location is found at the point of tangency of a line parallel to the draft line. Exhibit 6 is a typical example of the above technique for determining required storage.

g. Allowable draft versus storage. Exhibits 7, 8, 9, 10, and 11 show curves of allowable draft versus storage adjusted to 44-year base period 1912-1955 for the Brandywine, Christina, White Clay, Red Clay, and Shellpot streams respectively. In some cases, the curves were extrapolated to the 300 mg/sq.mi. storage. The differences between pairs of gages on the same stream (Chadds Ford and Wilmington on the Brandywine, and the gages above Newark, and Near Newark on the White Clay) were so negligible that no adjustments were warranted.

h. Graphical displays of lowflows of 5 streams. Exhibits 12, 13, 14, 15, graphically depict selected values from Table 3, namely the lowest mean discharge for 7 and 120 days for the 2-and 10-year recurrence intervals for 5 streams in Northern Delaware. It can be seen that the Brandywine, White Clay, and Red Clay exhibit similar low flow characteristics. The Christina exhibits significantly lower discharges (mgd/sq mi) while the Shellpot has the lowest of the five streams.

The detailed calculation, tabulations, plots, and curves are on file with Dr. Paul Bock, Civil Engineering Department, University of Delaware, Newark, Delaware.

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1. The water Resources of Northern Delaware, W. C. Rasmussen, et al., State of Delaware, Delaware Geological Survey, Bulletin No.6, Vol. 1, June 1957, Newark, Delaware.

2. Report to the Levy Court of New Castle Co. on Water Supplies in New Castle Co., Whitman, Requardt and Associates, March 1956, Baltimore, Md. 33 pages plus appendices.

3. Order of Merit of Projects Selected for Study, by Russell Morgan, June 1958, 11 pages.

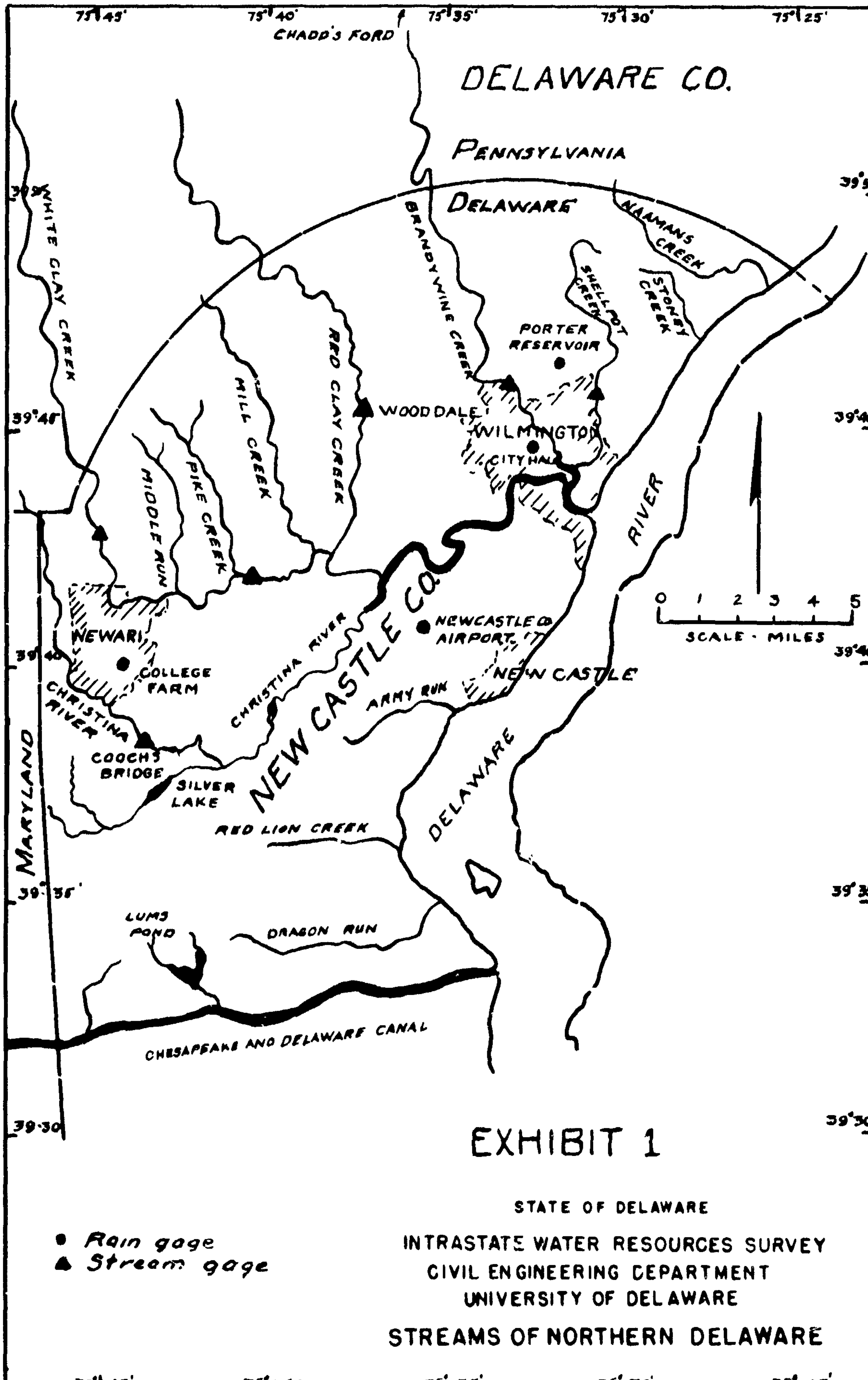


EXHIBIT 1

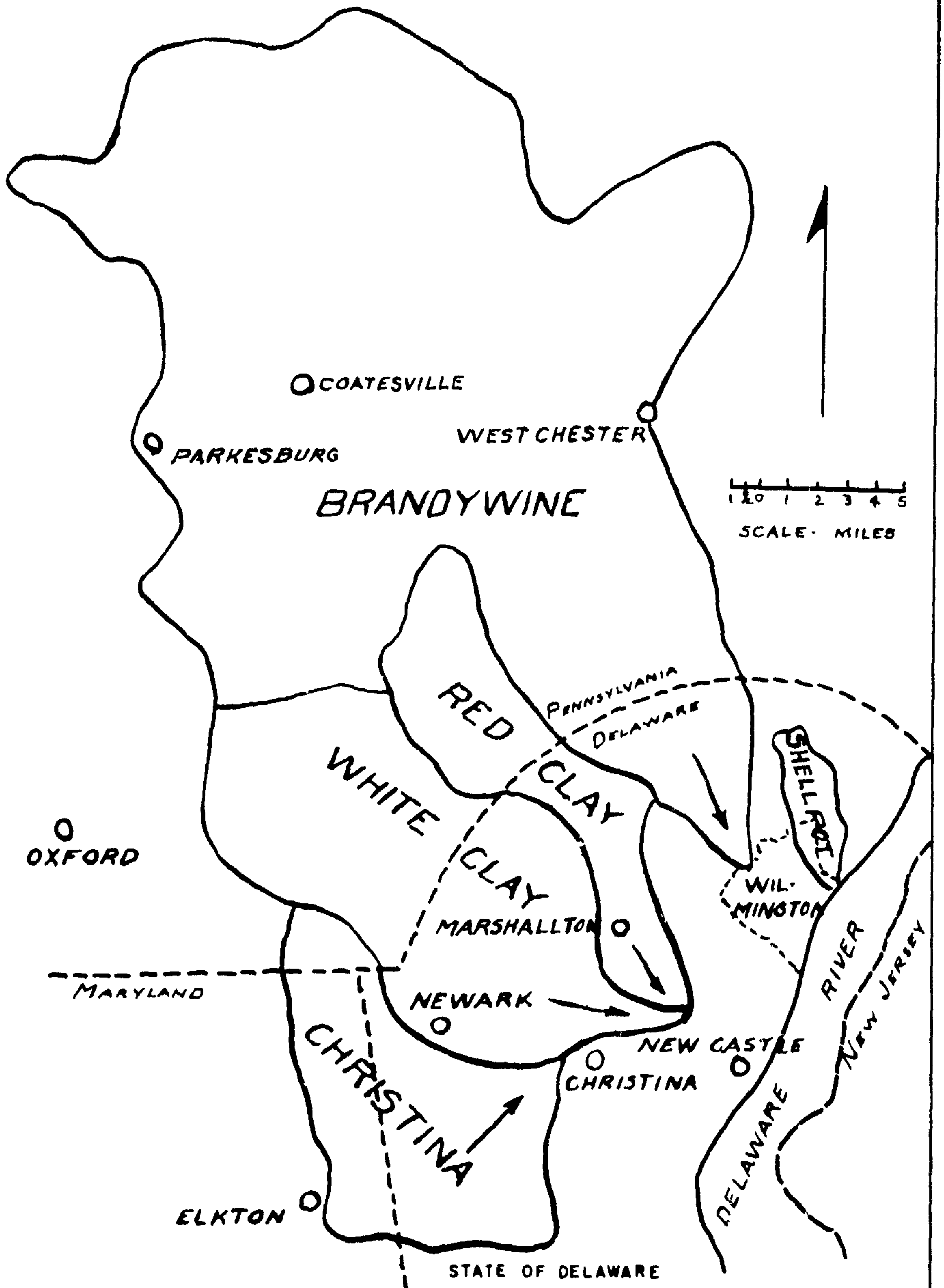
STATE OF DELAWARE

INTRASTATE WATER RESOURCES SURVEY

CIVIL ENGINEERING DEPARTMENT

UNIVERSITY OF DELAWARE

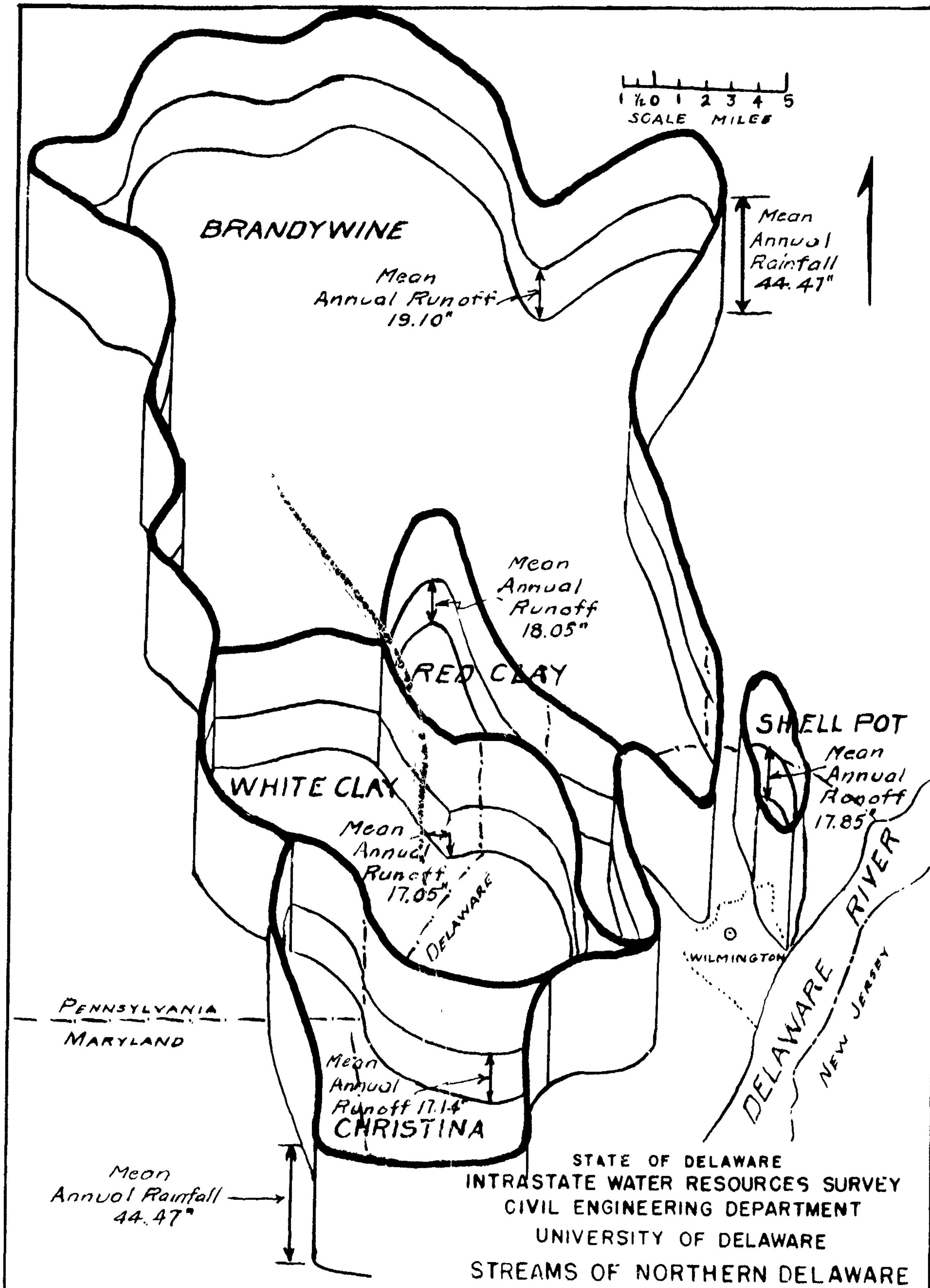
STREAMS OF NORTHERN DELAWARE



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
CIVIL ENGINEERING DEPARTMENT
UNIVERSITY OF DELAWARE

EXHIBIT 2

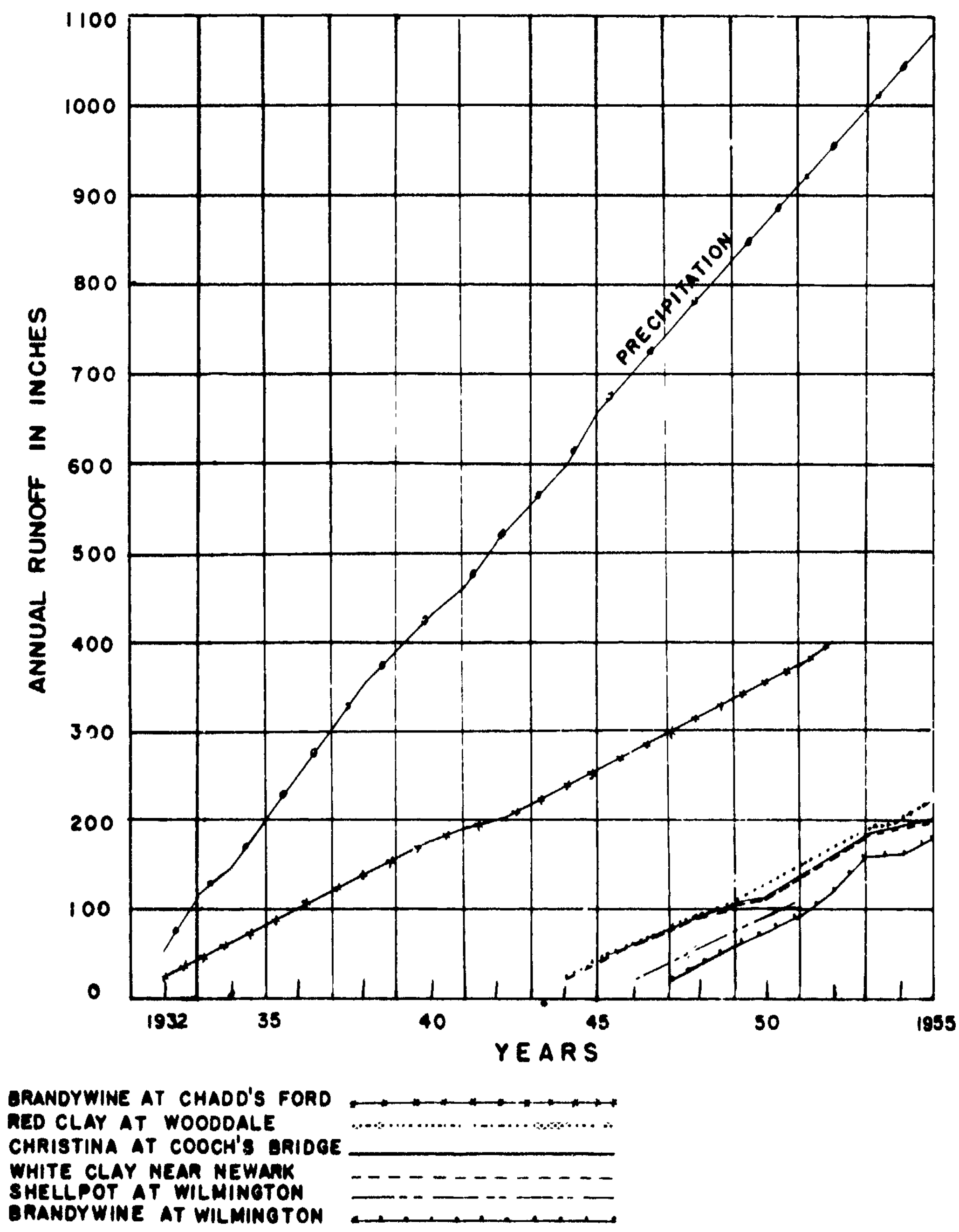
DRAINAGE AREAS
BRANDYWINE, RED CLAY, WHITE CLAY, CHRISTINA, SHELLPOT
STREAMS



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
CIVIL ENGINEERING DEPARTMENT
UNIVERSITY OF DELAWARE

STREAMS OF NORTHERN DELAWARE
MEAN ANNUAL RAINFALL AND RUNOFF
IN INCHES

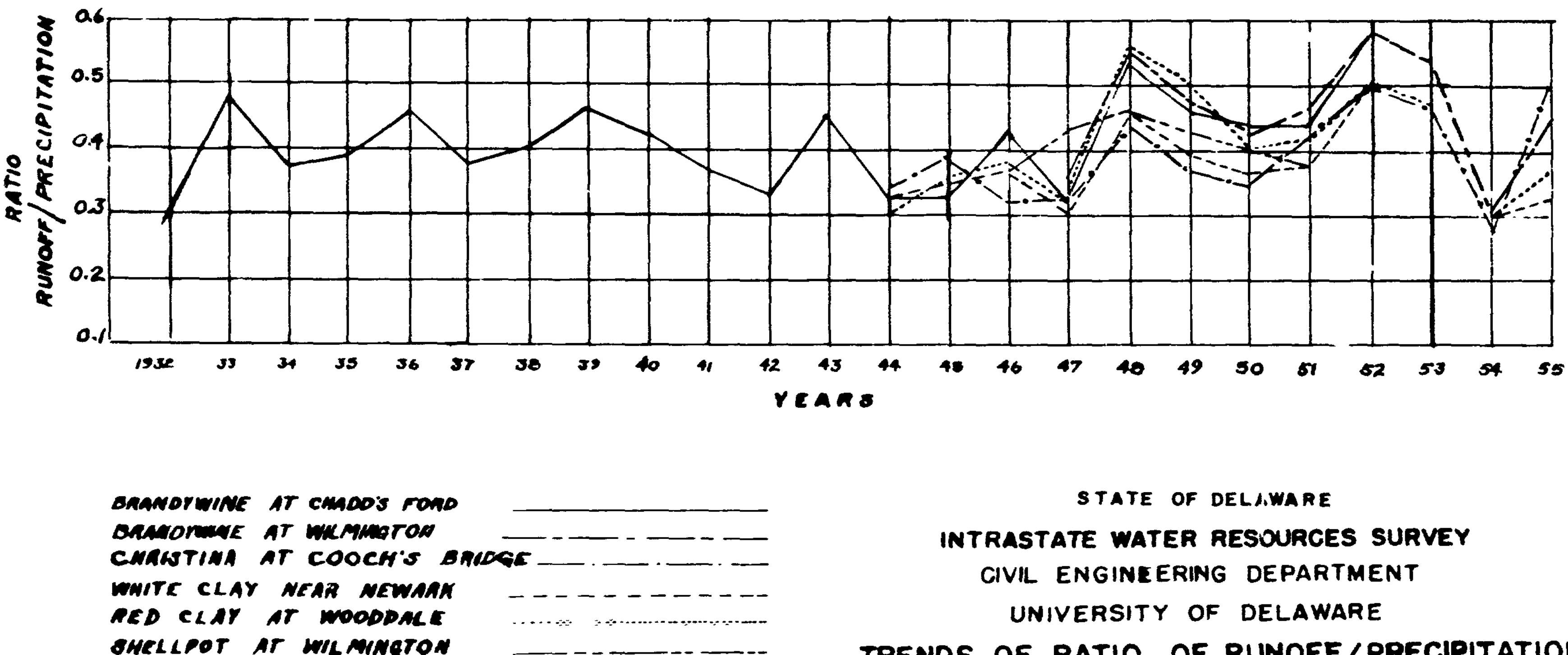
EXHIBIT 3



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
CIVIL ENGINEERING DEPARTMENT
UNIVERSITY OF DELAWARE

STREAMS OF NORTHERN DELAWARE
MASS RAINFALL RUNOFF CURVES

EXHIBIT 4



STATE OF DELAWARE

INTRASTATE WATER RESOURCES SURVEY

CIVIL ENGINEERING DEPARTMENT

UNIVERSITY OF DELAWARE

TRENDS OF RATIO OF RUNOFF/PRECIPITATION FOR STREAMS IN NORTHERN DELAWARE

EXHIBIT 5

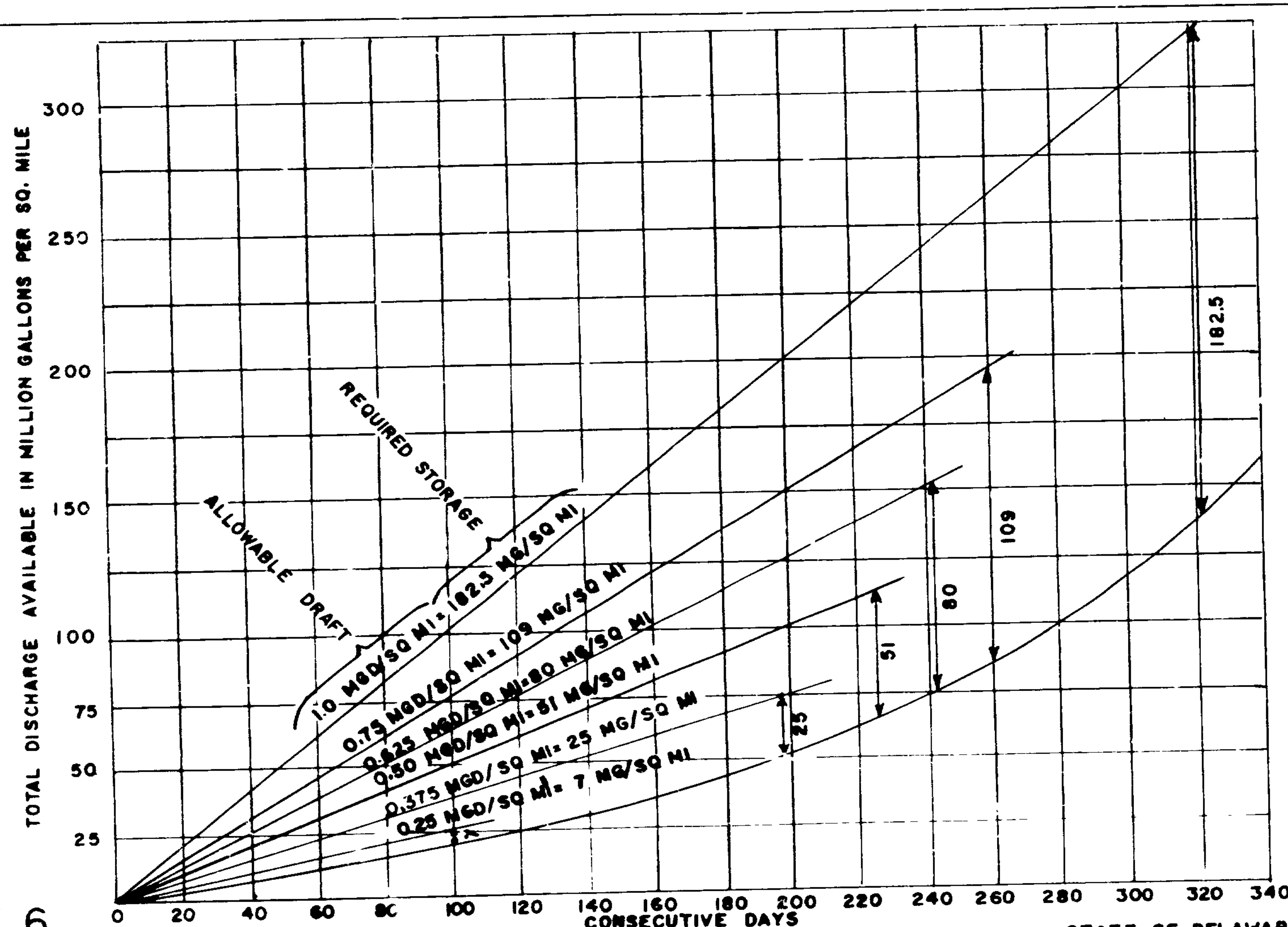


EXHIBIT 6

BRANDYWINE CREEK AT CHADD'S FORD
25-YEAR LOW FLOW DISCHARGE WITH VARIOUS DRAFTS AND REQUIRED STORAGES; 1912-1955 INCLUSIVE.

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
CIVIL ENGINEERING DEPARTMENT
UNIVERSITY OF DELAWARE

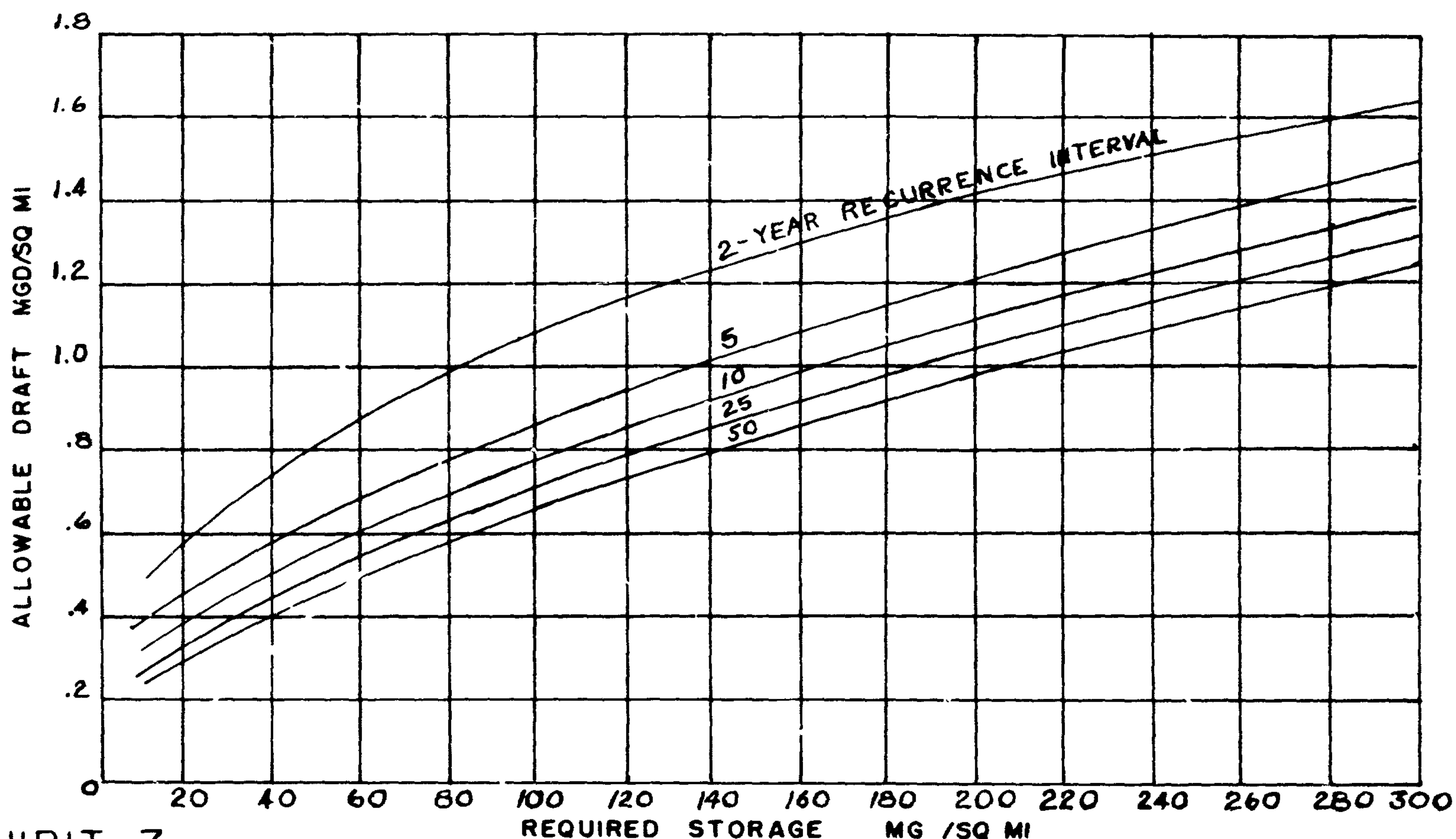


EXHIBIT 7

ALLOWABLE DRAFT VS. REQUIRED STORAGE
FOR BRANDYWINE CREEK
ADJUSTED TO 44-YEAR BASE PERIOD 1912-1955

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
CIVIL ENGINEERING DEPARTMENT
UNIVERSITY OF DELAWARE

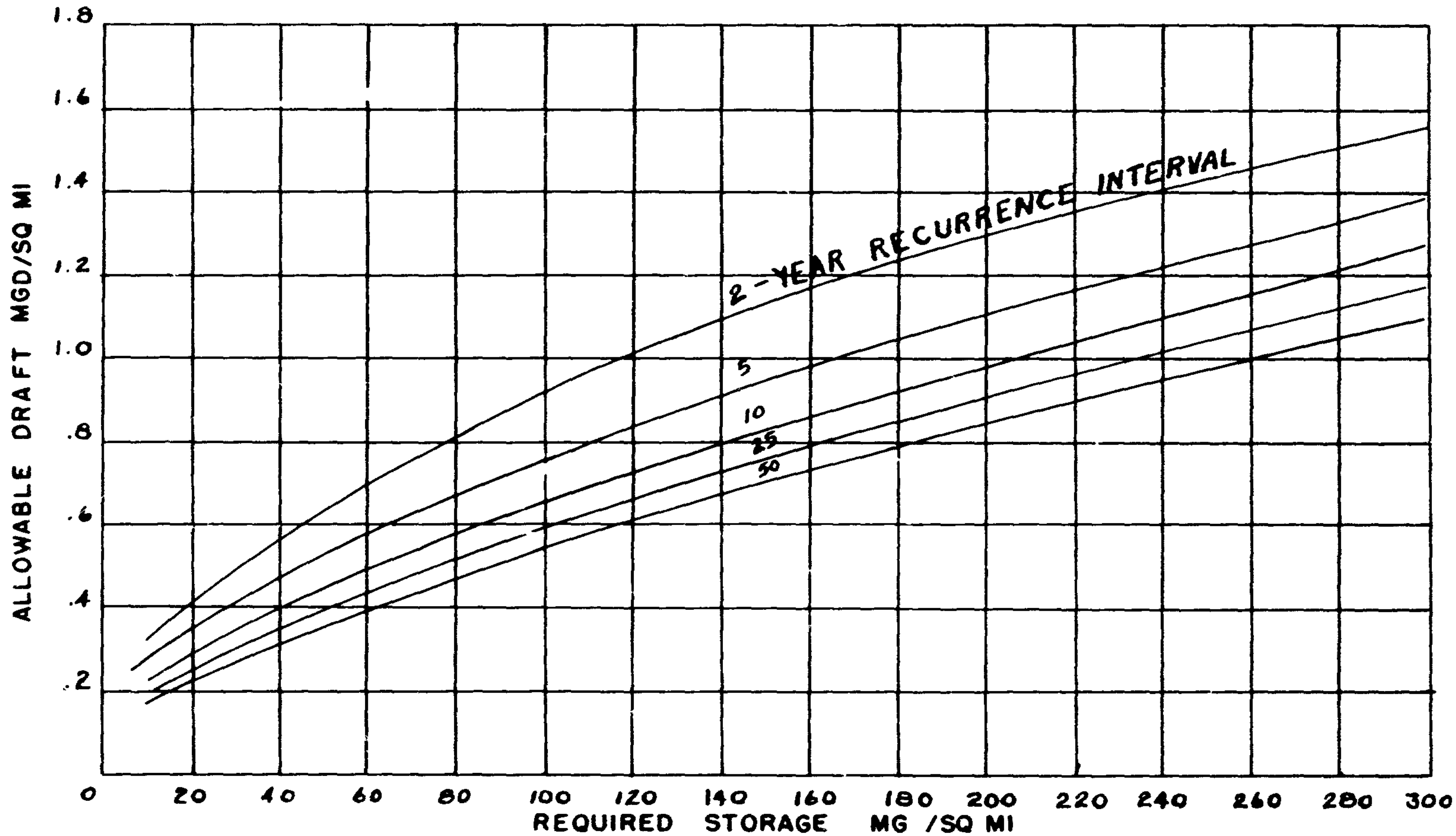


EXHIBIT 8

ALLOWABLE DRAFT VS. REQUIRED STORAGE
FOR CHRISTINA RIVER
ADJUSTED TO 44-YEAR BASE PERIOD 1912-1955

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
CIVIL ENGINEERING DEPARTMENT
UNIVERSITY OF DELAWARE

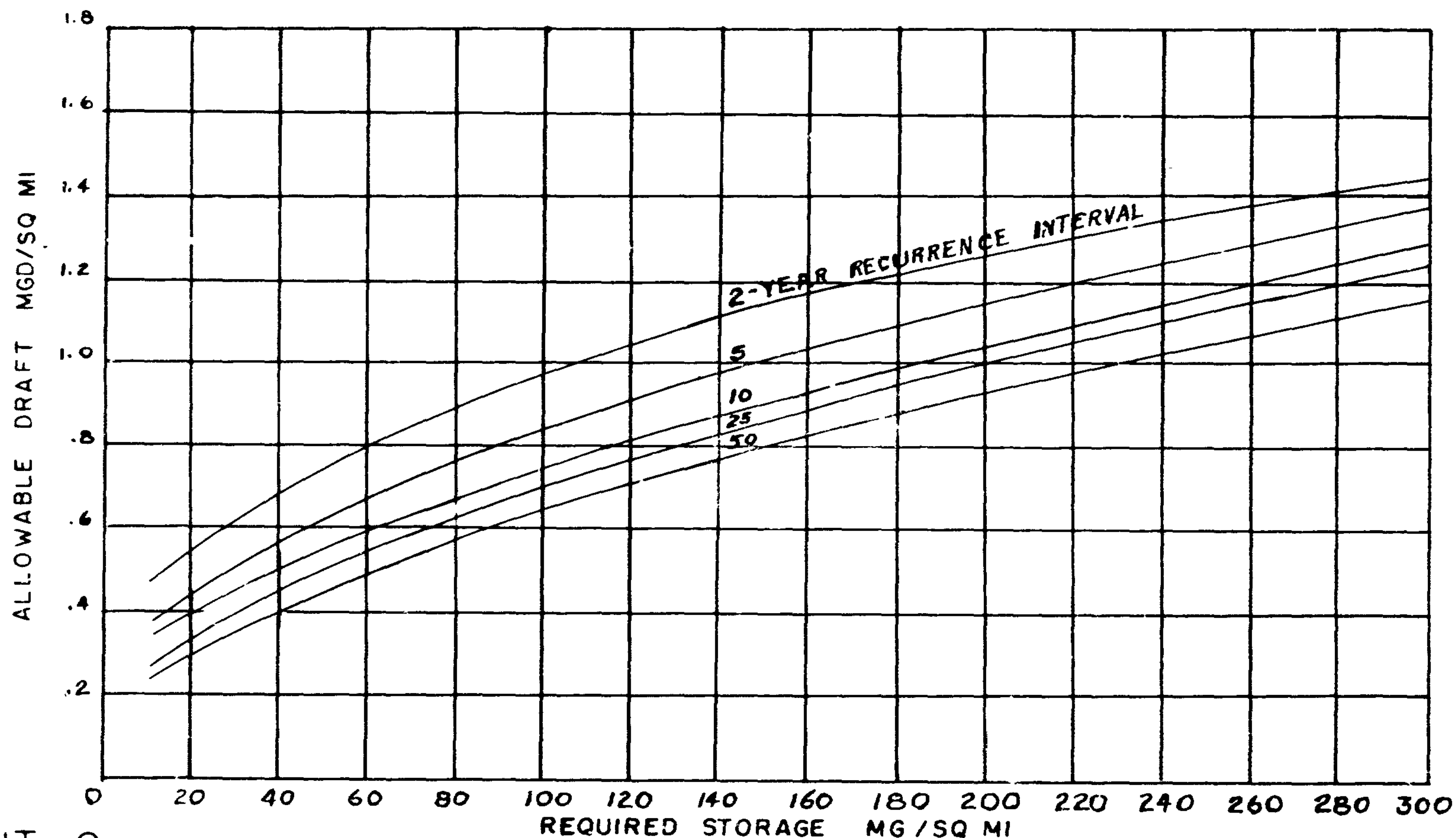


EXHIBIT 9

ALLOWABLE DRAFT VS. REQUIRED STORAGE
FOR WHITE CLAY CREEK NEAR NEWARK
ADJUSTED TO 44-YEAR BASE PERIOD 1912-1955

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
CIVIL ENGINEERING DEPARTMENT
UNIVERSITY OF DELAWARE

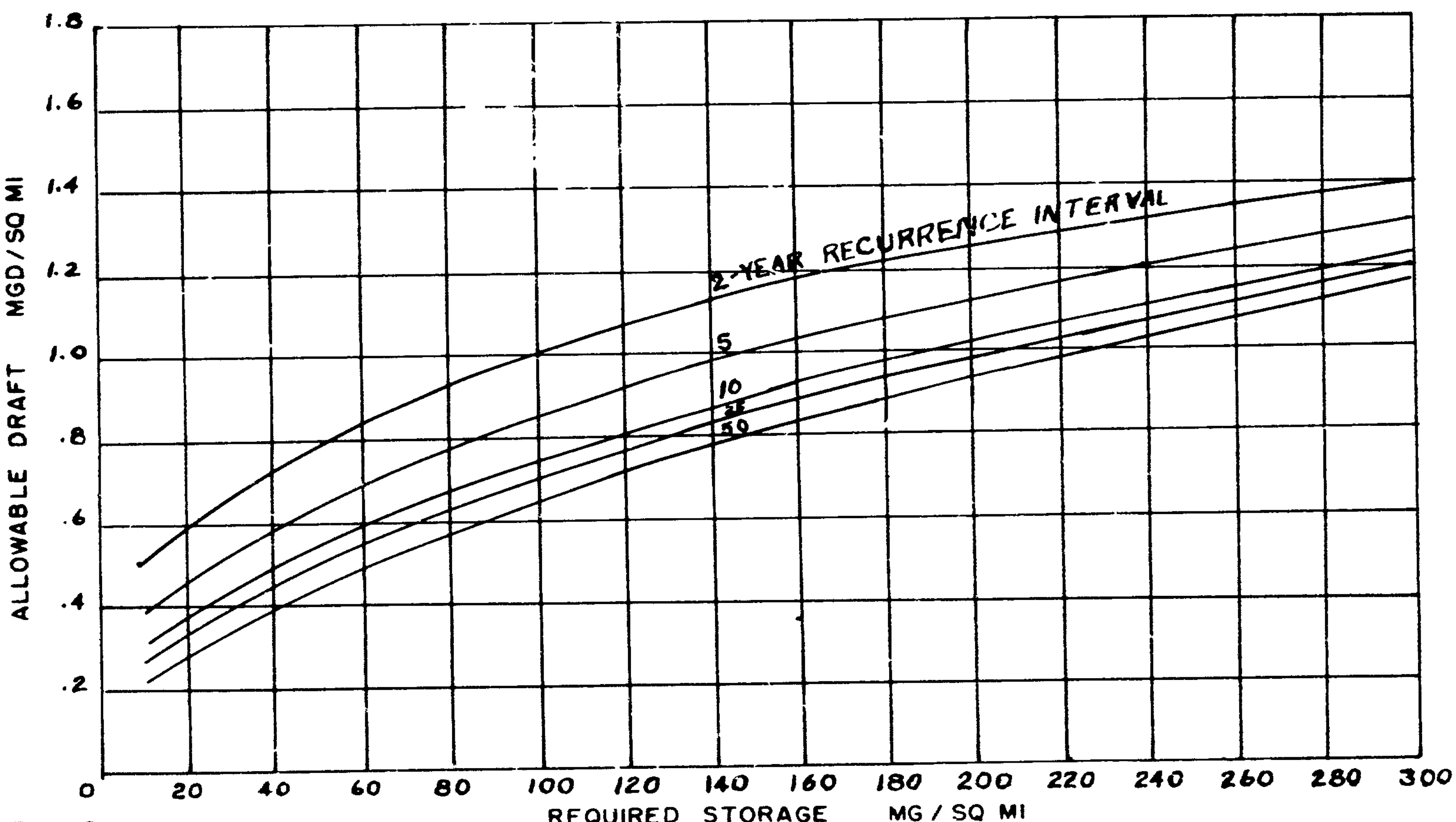


EXHIBIT 10

ALLOWABLE DRAFT VS. REQUIRED STORAGE
FOR RED CLAY CREEK
ADJUSTED TO 44-YEAR BASE PERIOD 1912-1955

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
CIVIL ENGINEERING DEPARTMENT
UNIVERSITY OF DELAWARE

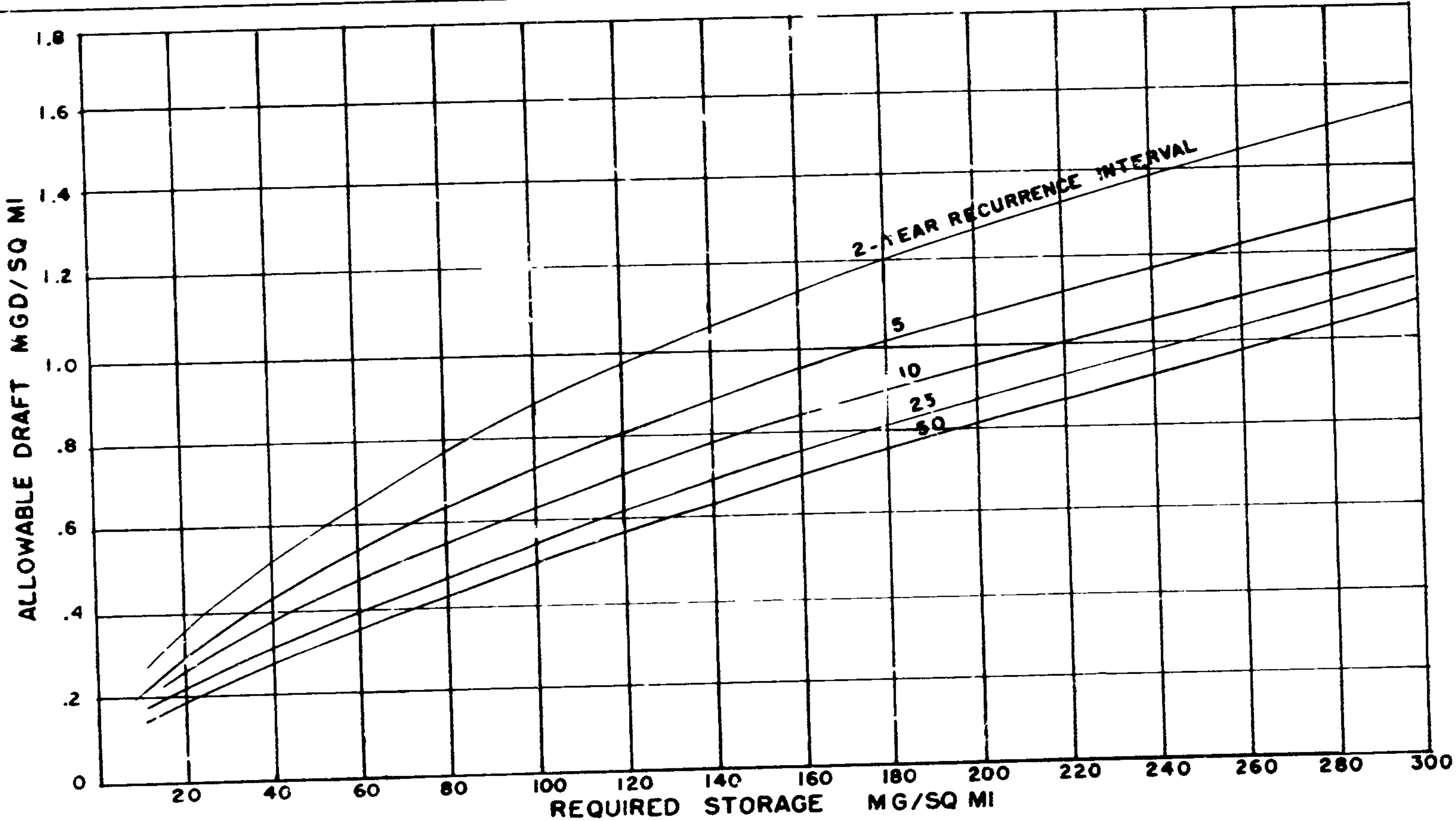
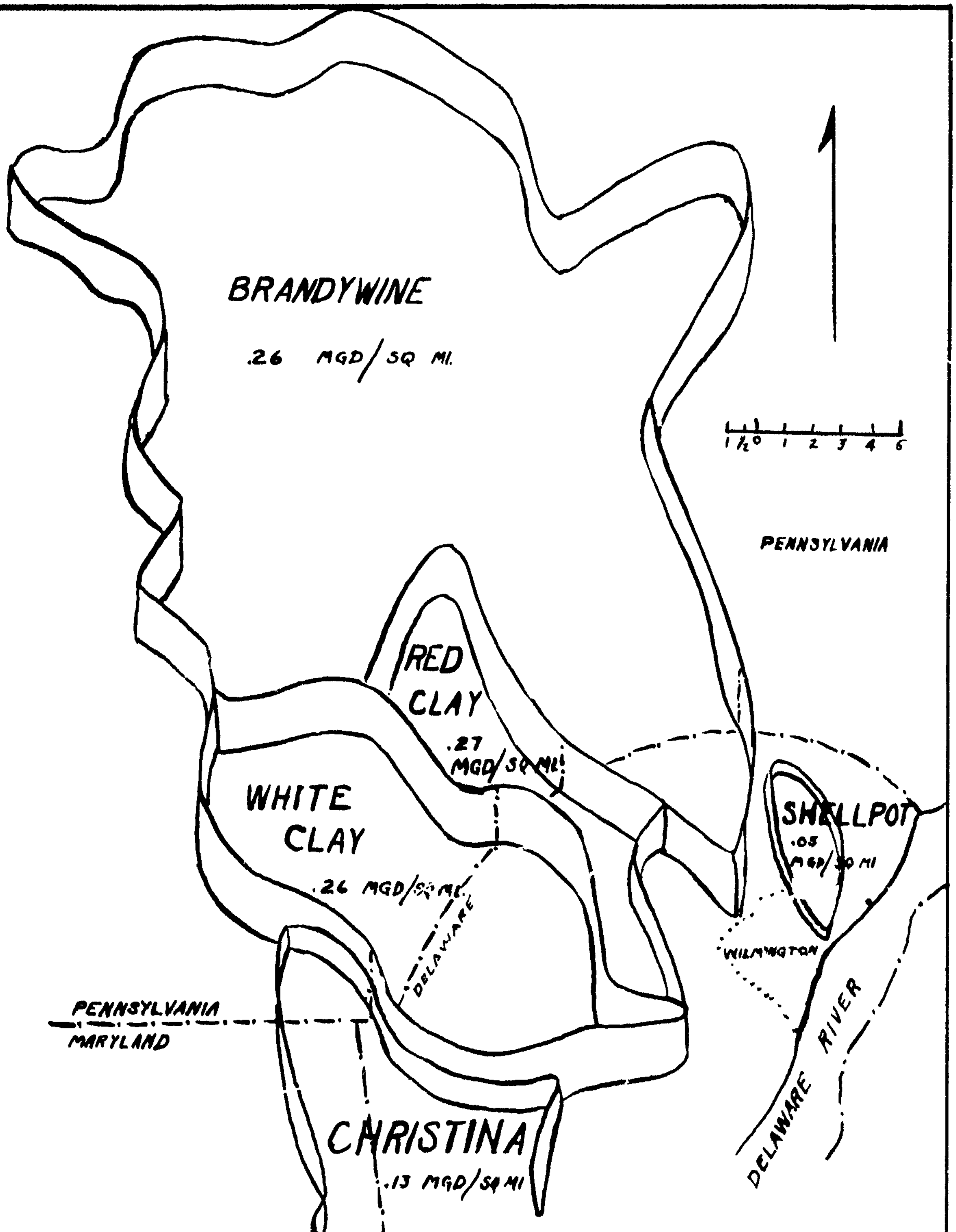


EXHIBIT 11

ALLOWABLE DRAFT VS. REQUIRED STORAGE
FOR SHELLPOT CREEK
ADJUSTED TO 44-YEAR BASE PERIOD 1912-1955

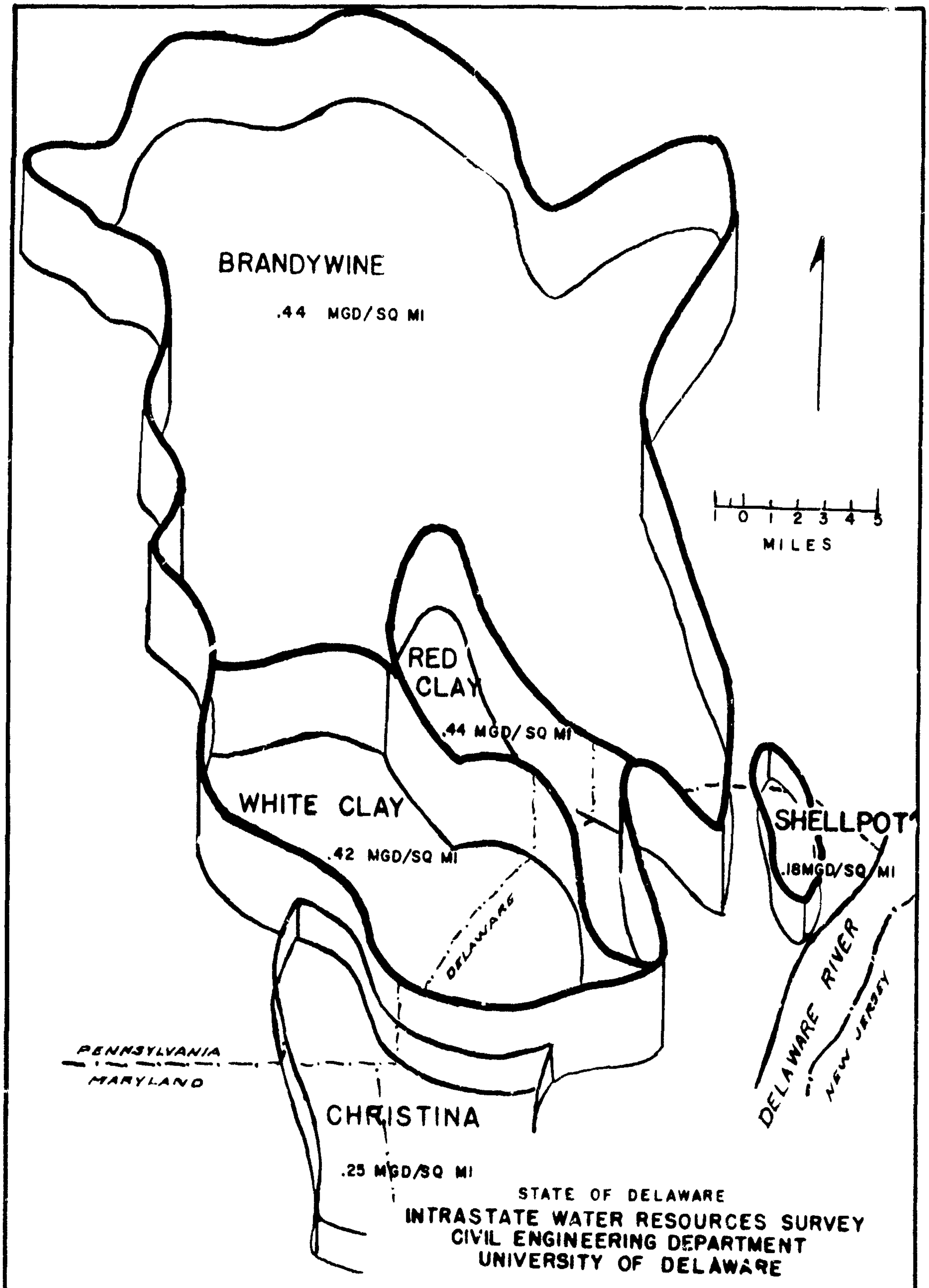
STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
CIVIL ENGINEERING DEPARTMENT
UNIVERSITY OF DELAWARE



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
CIVIL ENGINEERING DEPARTMENT
UNIVERSITY OF DELAWARE

STREAMS OF NORTHERN DELAWARE
2-YEAR RECURRENCE INTERVAL
LOWEST MEAN DISCHARGE FOR 7 YEARS
IN MGD PER SQUARE MILE

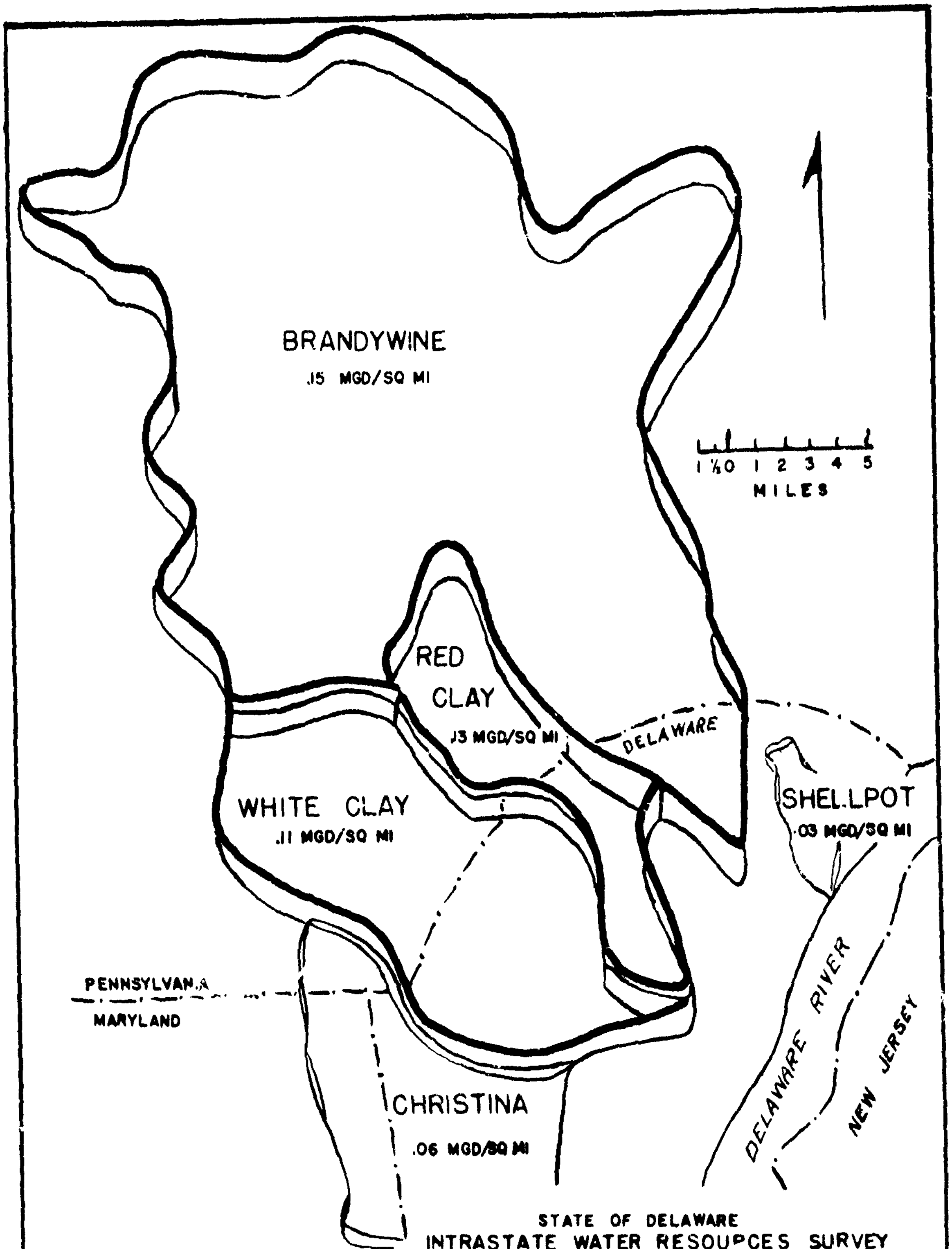
EXHIBIT 12



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
CIVIL ENGINEERING DEPARTMENT
UNIVERSITY OF DELAWARE

STREAMS OF NORTHERN DELAWARE
2-YEAR RECURRENCE INTERVAL
LOWEST MEAN DISCHARGE FOR 120 DAYS
IN MGD PER SQUARE MILE

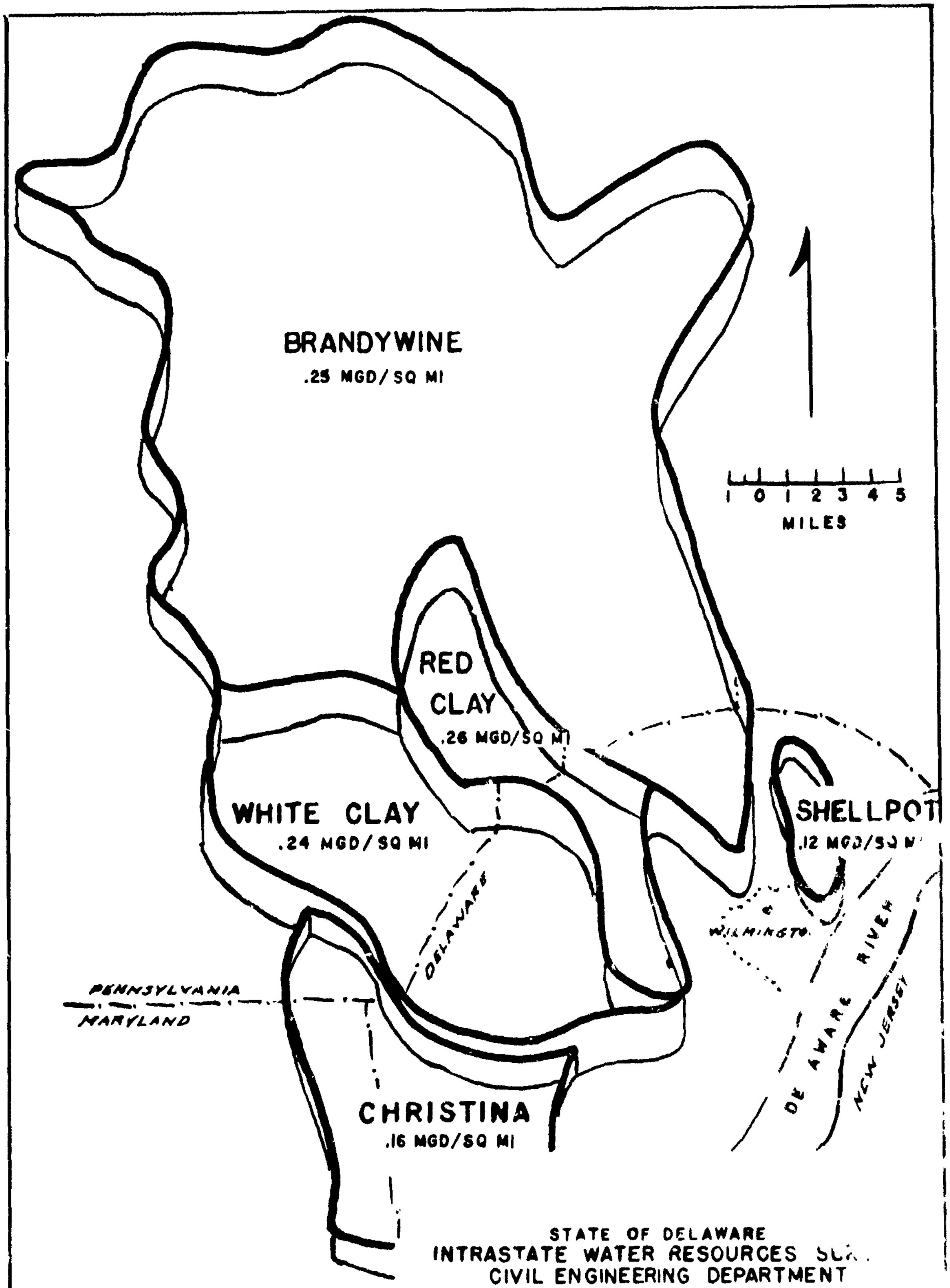
EXHIBIT 13



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
CIVIL ENGINEERING DEPARTMENT
UNIVERSITY OF DELAWARE

STREAMS OF NORTHERN DELAWARE
10-YEAR RECURRENCE INTERVAL
LOWEST MEAN DISCHARGE FOR 7 DAYS IN MGD PER SQUARE MILE

EXHIBIT 14



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SUR...
CIVIL ENGINEERING DEPARTMENT
UNIVERSITY OF DELAWARE

STREAMS OF NORTHERN DELAWARE
10-YEAR RECURRENCE INTERVAL
LOWEST MEAN DISCHARGE FOR 120 DAYS
IN MGD PER SQUARE MILE

EXHIBIT 15

SECTION XV

DELAWARE GEOLOGICAL SURVEY

15.01 FACTORS CREATING THE LAND USES WHICH EXIST TODAY IN DELAWARE

a. Location between Delaware and Chesapeake Bays. This location has tended to isolate the peninsular part of Delaware (south of the Chesapeake and Delaware Canal). This part of the state has, consequently, remained rural-agricultural, whereas the northern part has developed industrially because of its better communications. Location along the Delaware Bay and River has provided relatively inexpensive water transportation which has been so important for the industrial development of northern Delaware. The Delaware River is also a source of large quantities of water suitable as a coolant, although the salinity of the water makes it unsuitable for most other uses. Large industrial enterprises have been attracted by this factor.

b. Geologic and physiographic factors. Geologically and physiographically, Delaware can be divided into two major regions, the Piedmont and the Coastal Plain.

(1) The Piedmont is a hilly area of moderate relief underlain by crystalline rocks, and the Coastal Plain is a low-lying, flat area underlain by unconsolidated sediments, such as sands, clays, and gravels. These two areas are separated by the Fall Zone, a narrow zone in which the streams descending from the Piedmont often have rapids or falls. This major geologic and physiographic division has exercised great influence on the land use pattern of Delaware as well as that of other states along the Atlantic Coast.

(2) The Fall Zone. The early colonists had no other means of transportation available than ships and boats, and therefore they settled along the shores of the many estuaries of the Atlantic Coast. The Delaware River is one of these estuaries and the early settlements were founded in the Lewes area and in New Castle. The colonists, moving upstream, stopped at the Fall Zone because it prevented further navigation, and offered a site for the development of manufacturing owing to the availability of water power. Trenton, Philadelphia, Wilmington, Baltimore, Washington, DC, Richmond, and many other cities originally developed in the Fall Zone for these reasons.

(3) The Piedmont. The Piedmont comprises only 6 percent of the total area of Delaware, but it has natural resources of significance: surface water and, in general, fertile soils. The surface water resources are of particular importance to large population concentrations and industry, and also serve, to a limited extent, agricultural irrigation; their development is still in its infancy. The topography of the Piedmont is suitable for the construction of dams and storage reservoirs. Ground water is available only in relatively small quantities; well yields vary between 1 gallon per minute and 150 gpm, with a mean yield of about 10 gpm. Such small

quantities are usually adequate for domestic and farm use, but not for irrigation or industrial use. Some of the crystalline rocks of this area have been used as road metal.

(4) The Coastal Plain. The flat topography of the Coastal Plain has an important bearing on the development of its natural resources: there are few, if any, suitable sites for the construction of large storage reservoirs of surface water, and in many places natural drainage is poor, preventing the growing of crops unless drainage ditches are constructed.

The sedimentary formations of the Coastal Plain form large ground-water reservoirs. Optimum development of these reservoirs has not been accomplished, and ground water is abundant in many places.

Pleistocene (Ice Age) sands and gravels form the surficial deposits of the Coastal Plain. They are lacking in silts and clays in the southern part of the state, resulting in relatively infertile soils. The coarseness of these deposits promotes ground-water recharge.

In many parts of the Coastal Plain are shallow, rimmed depressions similar to Carolina bays. The centers of many of the depressions are swampy. They are, in general, oval or elliptical in shape. Their size varies from one acre to more than 1,000 acres, the smaller ones occurring in northern and central Delaware, and the larger ones in Sussex County. These basins are usually unsuitable for agricultural production, and they may play an important role in the recharge and evapo-transpiration of ground water.

15.02 FUTURE INFLUENCE ON POPULATION OF THE FACTORS WHICH ESTABLISHED PRESENT LAND USES

a. Location between Delaware Bay and Chesapeake Bay. The peninsular location of Delaware south of the Chesapeake and Delaware Canal will tend to become of smaller importance with the development of a highway system in connection with the Chesapeake Bay Bridge, or, in the future, with a bridge replacing the Cape Charles-Norfolk ferry. Location along the Delaware River will remain a physical factor of first-rate importance as long as transportation of bulk commodities by ship is more economical than by rail or truck. However, the wide Delaware estuary is devoid of natural harbors because the Coastal Plain streams entering the bay are too small to accommodate vessels of ocean-going size. With the construction of harbor facilities, frequent dredging may be necessary as tidal currents are expected to silt-up artificial harbors. The Delaware River will remain an important source of water supply for cooling.

b. Geologic and physiographic factors. (1) The Fall Zone. As described previously, the Fall Zone has been an important population generator. As a result of population concentration in the Fall Zone, the best highways and railways were located there. In turn, industry was attracted by good transportation facilities and other favorable factors. Thus, although the direct influence of the Fall Zone (its availability of water power) is no longer important, further population and industrial

growth must be expected in the area. The indirect influence of the Fall Zone will be felt for a long time.

(2) The Piedmont. The natural physical factors of greatest importance to the development of northern Delaware in the future are the availability of surface-water resources and the topographic features necessary for the construction of large storage reservoirs. These physical factors will enable further population concentration in northern Delaware.

(3) The Coastal Plain. The availability of ground-water supplies will probably be the controlling physical factor in the development of the Coastal Plain. Industry to which water transportation is not essential, but which needs moderate to large quantities of water, may develop, particularly such light industry which would supply the needs for a population concentration in northern Delaware.

The industrialization and concentration of population in the northern Coastal Plain would necessarily be accompanied by the construction of many housing developments and roads. Such construction will tend to reduce ground-water recharge.

15.03 GROUND-WATER AVAILABILITY IN DELAWARE

The availability of ground water is a rather elusive quantity because it depends on many factors, most of which are difficult to determine in a quantitative manner. Such factors are: the extent, thickness, and physical properties of water-bearing rocks; the amount of water stored in them; the amount of water that enters each ground-water reservoir in a given time; the portion of this recharge that can be recovered with the techniques now available; the spacing of wells drawing water from each aquifer; the chemical and bacteriological quality of ground water from different sources; and, finally, the conservation measures which may be taken to protect existing ground-water resources.

The factors enumerated are not all of equal importance; as a matter of fact, their relative importance varies from aquifer to aquifer. For example, storage of large quantities of water in an aquifer does not necessarily mean great water availability because the physical properties of the aquifer may be such that it does not yield water readily. Therefore, the evaluation of the state's ground-water resources will be particularly concerned with determining, as accurately as possible, the limiting factors involved in ground-water availability.

Aquifers are lithologic units which coincide with, or are a part of, geologic formations. A review of the geologic formations of the state is therefore necessary. Because the geology of Delaware has been described before in a series of bulletins published by the Delaware Geological Survey (Groot, Organist, and Richards, 1954; Marine and Rasmussen, 1955; and Groot, 1955), a brief statement here is considered sufficient.

15.04 GEOLOGY IN RELATION TO GROUND WATER

Delaware lies in two geologic provinces: the Piedmont and the Atlantic Coastal Plain. The Piedmont is underlain by crystalline rocks of igneous and metasedimentary origin which generally yield only small quantities of ground water, sufficient for domestic and farm use, and the Coastal Plain is underlain by unconsolidated clastic sediments of Cretaceous age and younger. These sediments form a wedge greatly thickening toward the southeast, and consequently they reach a thickness of about 8,000 feet below Fenwick Island. They have been deposited on the subsiding crystalline rocks of the Piedmont since early Cretaceous time.

The coarse-grained sediments of the Coastal Plain (sands and gravels) form Delaware's principal aquifers. They are separated from each other by fine-grained sediments which serve as aquicludes, beneath which the water is artesian.

Table 1, on the next page, presents a summary of the geology of the state, and indicates the water-bearing characteristics of the geologic units recognized.

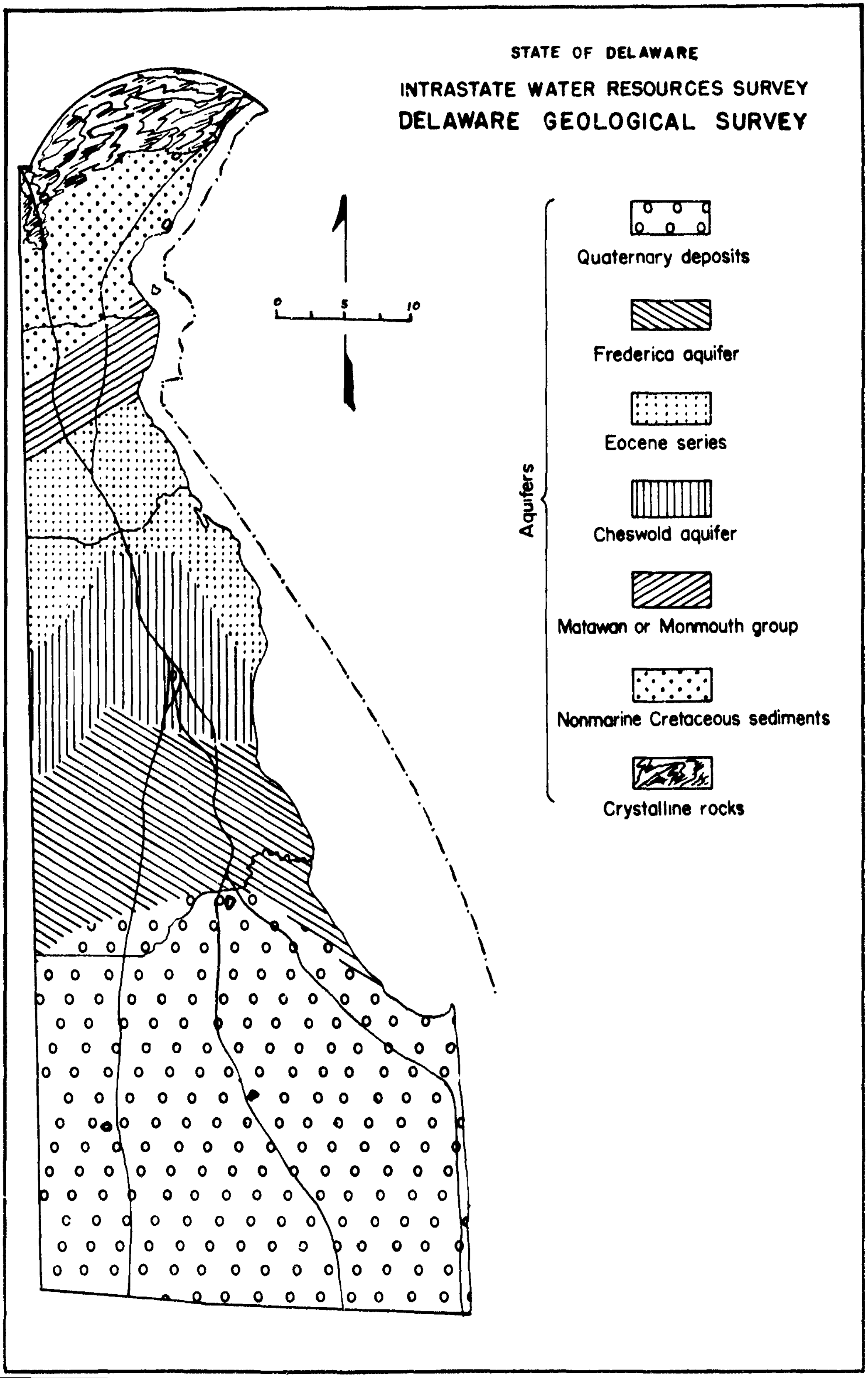
Figure 1, a map of Delaware on page 15-7, shows the geographic distribution of the major water-bearing sands in Delaware. The Pleistocene series also provides large-capacity wells in numerous areas of the Coastal Plain north of the boundary of the area of principal use.

TABLE 1. CHARACTERISTICS OF GEOLOGIC FORMATIONS IN DELAWARE

System	Geologic Units			Lithology	Water-Bearing Characteristics	Remarks
QUATERNARY	Alluvium and soil	Recent Series		Sand, gravel, silt, and clay in flood plains.	A few wells derive water from flood-plain sands.	
QUATERNARY	Fluviatile and estuarine deposits	Pleistocene Series		Sand and gravel primarily, some silt thickest in channel deposits.	High permeability in in general, particularly in channel deposits.	Wells with highest specific capacity in this aquifer.
TERTIARY	Upland sediments	Pliocene(?) Series	Bryn Mawr(?) gravel	Silt, sand, and gravel.	Yields small quantities of water in a few places.	
TERTIARY	Marine (?) sediments	Miocene	Yorktown Cohansey(?)	Blue and grey silts; grey fine to medium sands.	Yields small to moderate quantities of water to wells on eastern shore of Maryland.	Little is known about this formation in Delaware.
TERTIARY	Marine sediments		Kirkwood formation	Blue and grey silts and fine to coarse sands.	This formation contains 2 highly productive sands: the Frederica and Cheswold aquifers.	Locally deep cones of depression.
TERTIARY	Marine sediments	Eocene	Piney Point formation	Green sands, and silts	Expected to be very productive in Dover area and northern Sussex County.	Contains some brackish water near Leipsic.
TERTIARY	Marine sediments	Eocene or Paleocene	Aquia-Vincentown formation	Green sands, and silts	Good water-bearing sand.	Moderately hard water.
TERTIARY	Marine sediments	Paleocene	Bright Seat (?) formation	Green silts, and sands.	Capabilities unknown.	

TABLE 1. (Continued)

System	GEOLOGIC UNITS			LITHOLOGY	WATER-BEARING CHARACTERISTICS	REMARKS
CRETACEOUS	Marine sediments	Monmouth Group	Red Bank and Mount Laurel-Navesink formations	Reddish-brown medium and fine sand, and dark green silty sand and silt.	Red Bank, a minor aquifer; Mount Laurel-Navesink, an aquiclude.	Formations recognizable in outcrop facies changes downdip.
		Matawan Group	Wenonah sand, Merchantville clay	Rust-brown and grey sand, and blue silt.	Wenonah, a minor aquifer; and Merchantville, an aquiclude.	Formations recognizable in outcrop facies changes downdip.
	Transitional sediments	Upper Cretaceous	Magothy formation	Black carbonaceous clays and white sands.	Yields small quantities of water generally, but large amounts in a few places in the Middletown area.	
	Nonmarine sediments	Upper and lower Cretaceous	Raritan, Patapsco, and Patuxent formations undiff.	Grey, white, red, and yellow variegated clays; and white and grey sands in channels and lenses.	Yields moderate to large quantities of water to wells in the northern part of the Coastal Plain. Most important aquifer in New Castle County.	Water generally irony.
PALEOZOIC & PRE-CAMBRIAN (?)			Wissahickon formation, Cockeysville marble, and other crystalline rocks.	Schist, gneiss, marble, granite, and gabbro.	Small yield of water, generally adequate for domestic purposes only.	


STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE GEOLOGICAL SURVEY
0
5
10
Aquifers
Quaternary deposits
Frederica aquifer
Eocene series
Cheswold aquifer
Matawan or Monmouth group
Nonmarine Cretaceous sediments
Crystalline rocks

a. Discussion of aquifers. (1) Paleozoic and Pre-Cambrian (?) crystalline rocks. These rocks form an aquifer which is generally adequate for water use for domestic and farm purposes, but absolutely inadequate for large-scale industrial or municipal uses. Wells producing 50 gallons per minute (gpm) are scarce, and in many areas yields seldom exceed 10 gpm. The crystalline rocks form, therefore, only a minor aquifer which can not be expected to contribute significantly to the water resources of the state.

Production of ground water could be significantly increased only by developing a great number of closely-spaced wells. In view of the high cost involved, such a drilling program would not be realistic.

(2) Nonmarine Cretaceous sediments. The nonmarine sediments of Cretaceous age form the most important aquifer in New Castle County north of the Chesapeake and Delaware Canal. They supply ground water to major industries, including the Tidewater Oil Company.

Owing to their nonmarine origin, their physical characteristics vary greatly within relatively short distances, and accurate prediction as to their water-producing capabilities is possible only in areas for which detailed information is available.

The nonmarine sediments are hardly used as a source of water supply in southern New Castle County, and significant development of these aquifers may occur in the future.

The quality of the water contained in the nonmarine Cretaceous is generally good, although a moderately high iron content is common. However, treatment of water for this mineral content is practicable.

In a recent report published by the Delaware Geological Survey (Rasmussen, et al., 1957) the nonmarine Cretaceous sediments are divided into 3 aquifers, alternating with aquicludes. Although such a division is a simplification of the true situation, it provides a practical working hypothesis. These aquifers are called the Lower, Middle, and Upper aquifers. The Lower aquifer is the most productive of the 3, yielding large quantities of water to industry.

As the sediments cross, in their outcrop belt, the Delaware River and the Chesapeake and Delaware Canal, the danger of salt water encroachment is present, and should be guarded against. This danger depends on the following factors:

(a) the lowering of artesian head as a result of pumpage;
(b) the degree of salinity of the water of the Delaware River and the Chesapeake and Delaware Canal; the higher the salt content of these bodies of water is, the more serious salt water encroachment problems will become.

It should be noted that the Lower aquifer crosses the Delaware River between Wilmington and the Delaware Memorial Bridge; this area is at a greater distance from the center of heavy pumpage near Delaware City than the

outcrop areas (below the River) of the Middle and Upper aquifers. Consequently, salt water encroachment is more likely to occur in the Middle and Upper aquifers than in the Lower aquifer.

(3) The Magothy formation. The Magothy formation is transitional between the nonmarine deposits and the marine Upper Cretaceous formations; it consists of swamp and lagoonal deposits, and, downdip, probably of shallow-water marine sediments. The formation forms a minor aquifer, which sometimes functions as one hydrologic unit with the Upper aquifer of the nonmarine Cretaceous sediments. In many places in New Castle County it is absent.

Only two high-capacity wells are known to derive water from the Magothy; both wells are located southwest of Middletown.

In the central and southern portion of the state the formation probably contains brackish water; in a test hole drilled at the Dover Air Force Base the electric log indicates good permeability, but the low resistivity shown opposite Magothy and nonmarine Cretaceous sands suggests saline water.

(4) Wenonah sand. The Wenonah sand forms a minor aquifer from which small to moderate yields are obtained in wells in southern New Castle County. Downdip, in Kent County, facies changes occur, and the Wenonah can not be distinguished from other sediments of the Matawan group.

(5) Red Bank sand. This formation occurs in the vicinity of the Chesapeake and Delaware Canal. Due to its very limited thickness it forms only an aquifer of minor importance. It has not been traced downdip. It is known, however, that it can not be spearated from other sediments of the Monmouth group in the Dover area. The water derived from the Monmouth group is usually hard; drillers often bypass Monmouth sands to obtain water of better quality from deeper aquifers.

(6) The Aquia formation. The Aquia consists of green sands and silts in outcrop, and the same materials have also been found in wells. Large-scale production of water from the sandy portion of the formation is, however, not known, and this may be caused by the fact that it contains hard water. The capabilities of this aquifer are not well understood.

(7) The Piney Point formation. The Piney Point formation consists of glauconitic sands of Jackson (upper Eocene) age. The aerial extent of this aquifer has not been determined as yet, but it is known to be present below central Kent County, and northern Sussex County; it has been identified in wells near Leipsic, Dover, Milford, and Bridgeville. In a well recently drilled at the Dover Air Force Base the Piney Point was found to be 250 feet thick, and highly productive. It must be considered an aquifer of great promise. Unfortunately, in a well near Leipsic it contained water about 900 ppm chloride, and the danger of salt-water encroachment should therefore be closely watched. It is possible, however, that this high-chloride water in the Leipsic area is a pocket of brackish water infiltrated into the aquifer during a higher stand of sea-level during the Pleistocene, and that it is not due to salt-water encroachment going on at present.

(8) The Cheswold aquifer. This aquifer is a sand in the lower part of the Kirkwood formation. It is highly productive in the Dover area, and the city, Air Force Base, and local industries derive nearly all of their water supply from it. Unfortunately, a large cone of depression has developed in the piezometric surface of this aquifer. The water level in a well drilled for the Farmers Bank in 1952 was 77 feet below land surface, indicating a general decline of about 80 feet since 1893 when the first well was drilled (at that time the wells were reported as flowing, with a head a few feet above land surface).

(9) The Frederica aquifer. The Frederica aquifer is formed by a sand in the upper portion of the Kirkwood formation. It underlies southern Kent County; and yields large quantities of water to wells in the Milford area. A large cone of depression has developed in this area, and records indicate a water-level decline of at least 60 feet in the last 40 years.

(10) Sands of the Pliocene (?) series. Pliocene sand, silt, and gravel is found in a relatively small area north and northwest of Wilmington. These materials overlie the gabbroic rocks, and reach a maximum thickness of 60 feet. Generally their thickness is much less, severely limiting their potential. Only small domestic wells have been developed in the Pliocene series.

It is possible that some of the sand and gravel overlying the Miocene sediments in the Coastal Plain is of Pliocene (?) age. However this may be, they would form a hydrologic unit with the Pleistocene series, and therefore are not further considered in this section.

(11) The Pleistocene series. The Pleistocene sediments form the most extensive and accessible aquifer in Delaware; it receives direct recharge because it occurs at the surface. Owing to the generally coarse texture of the material, high-capacity wells have been successfully developed in it, particularly in areas underlain by buried channel deposits having a thickness of 80 feet or more. In the interchannel areas, however, the Pleistocene sediments are thin, at least in New Castle County, and the yield of wells is greatly limited by lack of available drawdown. In Sussex County the Pleistocene sediments are over 50 feet thick nearly everywhere, and reach a maximum thickness of about 200 feet.

Owing to a lack of knowledge of upper Miocene sediments (Yorktown-Cohansey (?) formations) which are present in southern Sussex County beneath the Pleistocene series, the Pleistocene-Tertiary contact is not always accurately known, and, as a result, the thickness of the Pleistocene series is not known everywhere. In addition, little can be said about the capabilities of the upper Tertiary sands which may function hydrologically with the Pleistocene sands and gravels.

The Pleistocene aquifer, which may actually include some Tertiary sands, is the principal water-bearing formation in Sussex County, and is also highly productive farther north where channel deposits occur.

15.05 POTENTIAL PRODUCTIVITY OF AQUIFERS

A few years ago W. C. Rasmussen (1955) made an estimate of the magnitude of the ground-water resources of Delaware, and more recently, Rasmussen, Groot, Martin, McCarren, Behn, and others (1957) published their appraisal of the water resources of Delaware north of the Chesapeake and Delaware Canal. The data presented here are based, in part, on this previous work.

.. Ground-water potential. Estimated ground-water potential is calculated separately for northern Delaware (north of the Chesapeake and Delaware Canal) and southern Delaware. This procedure has the great advantage of providing estimates for areas which are experiencing industrial expansion and population growth at quite different rates.

Rasmussen (Rasmussen et al., 1957) states (pp. 192-194):

"The recharge estimates for the aquifers are given in the following table and were determined by multiplying the average amount of precipitation on the outcrop area of each aquifer by a percent of infiltration for each aquifer. The average amount of precipitation on the outcrop area was calculated by multiplying the average precipitation in northern Delaware (44.1 inches per year, or 2.13 mgd per square mile) by the area of outcrop as measured by planimeter from the geologic map. The percent of infiltration for the Pleistocene series was estimated to be 50 percent and was based on a comprehensive water-budget study in the Beaverdam Creek basin near Salisbury, Maryland, 5 to 15 miles south of the Delaware State Line (Rasmussen and Slaughter, 1955, p. 126). The percent of infiltration for each of the other aquifers was estimated by comparing its grain size, sorting, and siltiness with those of the Pleistocene series.

"However, only a portion of this recharge is recoverable by pumping from wells without damage to other users, or without exorbitant expense to operate wells of low capacity or wells in undesirable locations. The tabl gives conservative estimates, by aquifer, of that portion of the recharge that would be available to wells in addition to the quantities now pumped. The estimates of total recoverability range from 10 to 50 percent for the different aquifers and are based on the writer's judgment in the light of all available data. When compared to present use, they indicate that the additional available ground water in northern Delaware is somewhat more than twice the present use.

"This estimate is conservative and does not take into account factors, some economic and some hydrologic, that would tend to increase the estimate. For example, the value of water may increase and it may be economical to develop more extensive well fields and less productive wells than are contemplated in the estimate given in the table. Lowering the water table by pumping will tend to increase infiltration in some areas, and, hence, increase recharge and decrease losses by evapotranspiration. Works for recharging aquifers artificially have been successful in many places. Surface water, such as flood runoff that is not easily stored or developed by other means, may be used for recharging the aquifers through a system of basins or canals. Thus it may be possible to pump not less than twice and perhaps as much as five times as much water from the aqui-

fers of northern Delaware as was pumped in 1955.

"Again it should be pointed out that these estimates are extremely rough and should be revised as additional data become available."

Estimated Recharge to Aquifers in Northern Delaware
and Portions Recoverable by Pumping of Wells

Aquifer	Estimated Recharge (mgd)	Estimated portion of recharge available to wells in addition to present pumpage. (mgd)
PIEDMONT		
Cockeysville marble	1	0.2
Wissahickon formation	23	2.3
Gabbro	7	.6
Granodiorite	1	.1
Miocene (?) series	3	.5
COASTAL PLAIN		
Nonmarine Cretaceous		
Lower aquifer	16	4.3
Middle aquifer	14	4.0
Upper aquifer	6	1.9
Transitional Cretaceous		
Magothy formation	2	.4
Marine Cretaceous		
Wenonah sand	4	.7
Mount Laurel sand and Navesink marl	1	.1
Red Bank sand	4	.4
Pleistocene series	27	8.4
Total	110	24

It should be understood that obtaining ground water in excess of twice the 1955 use in northern Delaware would involve considerable difficulties and expenditures, and would not be feasible if other water supplies could be developed at lower cost.

In Delaware south of the Chesapeake and Delaware Canal the Wenonah sand, the Aquia formation, the Piney Point formation, the Cheswold and Frederica aquifers, and the Pleistocene sediments are, and will be, the main sources of ground-water supply.

On the basis of the same assumptions as those used in estimating potential ground-water resources in northern Delaware, the following table can be presented for southern Delaware:

Estimated Recharge to Aquifers in Southern Delaware
and Portions Recoverable by Pumping of Wells

Aquifer	Estimated Recharge (mgd)	Estimated portion of recharge available to wells in addition to present pumpage. (mgd)
Wenonah sand	7	1.1
Aquia formation	25	2.5
Piney Point formation	0*	7.0
Cheswold aquifer	40	7.0
Frederica aquifer	40	8.0
Pleistocene series	1600	400.0
Total	1742	418.6

* The Piney Point formation is not known to have an intake area beneath the Pleistocene deposits. It is possible that it receives recharge from the Aquia formation or the beds of the Miocene series, across the bedding planes.

b. Significance of the estimates. It is necessary to make some remarks pertaining to the accuracy and the significance of the estimates presented above.

(1) It is impossible at present to estimate the amount of recharge to specific aquifers accurately. Few detailed investigations have been made owing to the complexity of the necessary measurements and their high cost. Recharge computations are based on the assumption that the coefficient of infiltration is 50 percent of the precipitation, and this may not always be realistic. As the amount of recharge determines the ultimate safe yield of an aquifer, this important quantity is not well known in most areas.

(2) Recoverable recharge is only a portion of the actual recharge, depending, among other things, on the texture of the aquifer and the spacing of wells. For instance, the coarse sands and gravels of the Pleistocene series will permit a relatively high recoverable recharge, whereas the fine sands of the Wenonah are expected to have a low percentage of recovery. In order to obtain the quantities of water potentially available, optimum well-spacing will be necessary.

On the other hand, the figures do not include water that is potentially available by artificial recharge, or means of reducing evapotranspiration losses.

(3) Even if recoverable recharges were known accurately, the question arises whether or not such quantities of ground water could be developed economically. There are aquifers which store considerable quantities of water, but which will only yield it if a very large number of wells were constructed--a procedure which will be, in some cases at least, so uneconomical as to preclude actual development.

(4) Any estimates of potential resources are valid only if salt water encroachment into aquifers can be prevented. With increasing ground-water withdrawal the encroachment danger becomes more serious. It should be noted that all important aquifers underlie, in outcrop or below Quaternary sediments, the Delaware and Chesapeake Bays, and are therefore in contact with brackish water.

(5) It is assumed that the quality of water found in the aquifers discussed is suitable for most uses.

The estimated portion of recharge available to wells in addition to present pumpage is very small in the area north of the Chesapeake and Delaware Canal; at the same time the most rapid economic development and population growth will occur there. When ground-water requirements will be twice as large as they are at present, full development may have been achieved unless conservation measures are taken. Such measures may be: (1) artificial recharge through spreading operations or input wells, particularly in the Pleistocene series, with flood waters from fresh-water streams; (2) the construction of check dams in tidal streams creating small reservoirs, along the borders of which well-fields could be developed. The cost of these conservation measures would have to be compared with that of development of surface-water supplies obtainable from Piedmont streams through the construction of dams, reservoirs and filtration plants.

Whereas the ground-water potential north of the Canal is about twice present usage, the situation south of the Canal is more favorable. Large quantities of ground water still await development, (although full development will only be accomplished with adequate planning) particularly in the Pleistocene and Miocene series; the Piney Point formation of the Eocene series is not known as to its capabilities, but, it can probably contribute materially to the water supply of central and southern Kent County. If a potential of about 400 million gallons a day is a reasonable estimate, the southern part of the state can look forward to more than a twenty-fold increase in water requirements, subject of course to the proper development procedures and economic feasibility.

Although this large quantity of water should be physically available, its full development is unlikely. Rural areas do not need so much water, and industry tends to gravitate to specific localities--along the Bay, near railroads or highways--and therefore local overdevelopment may occur in spite of large potential ground-water resources.

In view of this situation some thought should be given to physical and economic feasibility of concentrating ground-water development in areas underlain by relatively thick Pleistocene sands and gravels which are adjacent to bodies of fresh water, such as stream-fed ponds or reservoirs created by small barrier dams in tributaries to Delaware Bay and Chesapeake Bay. Batteries of high-capacity wells adjacent to such reservoirs may be capable of great sustained yields in relatively small areas. If, for instance, a total of 200 wells could be constructed at 10 to 20 sites, a yield of about 280,000,000 gallons per day could be achieved, assuming production of 1,000 gpm per well. This supply of water would be augmented by the yield of water from wells scattered throughout the state. However, detailed geological and engineering investigations will be needed to prove the feasibility of such large-scale production.

c. Conclusions. The potential ground-water resources of the state are estimated but not proved to be about 400 to 450 mgd. Such a quantity of water would be physically available under optimum conditions of development. However, it is realized that it will prove difficult, if not practically impossible, to achieve this completely, because an extensive network of pipelines would be required to transport water from many wells to places of use. Therefore, the utilization of ground water will be limited chiefly by economic factors, particularly south of the Chesapeake and Delaware Canal; north of the canal optimum development may be more nearly achieved because the economic necessity will be more compelling.

15.06 SALINITY INTRUSION IN COASTAL PLAINS AND METHODS OF CONTROL

a. Saline water occurrence. Saline water in aquifers may occur in several ways: (1) as a result of the gradual invasion of salt or brackish water into fresh-water-bearing sands; (2) as water trapped in a sediment during deposition (connate water); (3) as water which invaded a sediment during a high stand of sea level some time in the geologic past. These 3 types of saline water occurrence can not always be easily distinguished in nature, although this would be of great practical value. Whereas salt water invasion can be prevented, or combatted after it occurs, very little can be done about the other 2 types of saline water occurrence.

(1) Salt water invasion. Salt water encroachment occurs mainly in Quaternary deposits having a hydrologic connection with the water of the Delaware Bay and the Atlantic Ocean, particularly in those areas where heavy pumping lowers the fresh water head and thus induces the flow of water from the bay or ocean to the land. Areas where salinity intrusion has been noticed include Lewes, Rehoboth, and Fenwick Island. Potential encroachment danger is present, however, along the whole Delaware Bay shore and the Chesapeake and Delaware Canal, and if great development occurs in the future, salinity intrusion should be fought with vigor.

(2) Connate salt water. Connate water is present in some deep aquifers. In a test hole drilled at the Dover Air Force Base brackish water probably occurs in Cretaceous sands at depths below 1,100 feet according to the indications of the electric logs used in the test. Saline water is also present in deep sands at Salisbury, Maryland. Owing to the lack of deep wells the extent of the occurrence of connate water is unknown.

(3) Salt water left over from a previous high sea level. Brackish water that may have entered a sand of Eocene age during a previous high stand of sea level occurs in the Leipsic area. This water can not be of connate origin because the same aquifer contains fresh water of good quality downdip. It is also doubtful that this occurrence is an example of present salinity intrusion in view of the very limited water withdrawal from the aquifer.

b. Methods of control. Salt water encroachment can be prevented by a number of measures. They are:

(1) Limiting pumpage along the shore to such a degree that a fresh-water head is maintained at all times. This measure has the obvious disadvantage of limiting water utilization, or, forcing water-users to develop supplies at some distance from the coast or from aquifers which are not exposed to the danger of encroachment.

(2) Creation of a fresh water barrier by artificial recharge from fresh water streams; such recharge may be accomplished by water spreading, through ditches, or through recharge wells, depending upon local conditions; it would have as its main objective the maintenance of a fresh water head sufficient to prevent encroachment. These methods would all require detailed investigation as to their practicability and cost.

(3) Creation of fresh water lakes or ponds by the construction of small barrier dams across tidal streams; these lakes would be used to maintain a high fresh water head, and to recharge wells located around them. Investigations as to the possibilities of such measures should be made before their effectiveness can be determined, however.

15.07 FURTHER CONSIDERATIONS WITH REGARD TO UTILIZATION AND CONSERVATION OF WATER RESOURCES

a. Some problems involved in desalting water. A great variety of techniques for desalting saline water is in various stages of development under the guidance of the Office of Saline Water, U.S. Department of the Interior, and the University of California. Many of these techniques have been tried only on a laboratory scale, but some processes have been perfected to the point that the operation of saline water conversion plants has become a reality.

There is no doubt that saline water conversion is practical in some instances; it is now used, for instance, in Kuwait, Aruba, Curacao, Nassau (Bahamas), and a number of other localities where adequate fresh water resources are practically nonexistent. However, whereas technical possibilities are quite certain, economic feasibility is quite a different matter, except in regions lacking natural fresh water supplies.

All processes tried so far, and there are about 20, suffer from the basic difficulties inherent in saline water conversion: the need for a considerable amount of energy, and the high cost of the necessary equipment.

In the Saline Water Conversion Report for 1957, Secretary of the Interior Seaton made the following important statements: "The actual cost of large-output conversion of sea water today by conventional processes is $2 to $3 per thousand gallons." And he said, "It is open to question whether any radical or sudden advances in technology can be expected which would bring about a drastic reduction in the cost of conversion."

b. Conclusions. These statements, based on the latest scientific findings of many experts, leave little hope that saline water conversion will be economically feasible in areas where fresh water supplies can be obtained by developing aquifers or streams. Although it is not always easy to obtain figures on the cost of water supplies, Behn (Rasmussen, Groot, Martin, McCarren, Behn, and others, 1957) reported that complete operation and maintenance costs for the Chester, Pennsylvania, surface-water supply were about 8.9¢ per 1,000 gallons in 1955; Behn stated also that the cost of ground water for one large industrial enterprise in Delaware was, in 1955, somewhat less than 5¢ per 1,000 gallons, which may be compared with an estimate of 3.08¢ per 1,000 gallons reported for the total annual expense of Baltimore's industrial wells (Geyer, 1955). These figures indicate that the cost of saline water conversion is roughly 20 times higher than that of fresh surface-water supplies and about 40 times higher than that of ground-water supplies at present. Even if the cost of fresh-water supplies from surface-water sources were to increase 10-fold in the next few decades, they would be far less expensive than supplies obtained by salt water conversion. Therefore it must be concluded that saline water conversion is unlikely to provide an economical solution to Delaware's water problems during the next few decades.

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SECTION XVI

DELAWARE STATE BOARD OF HEALTH

16.01 SOURCE OF PUBLIC WATER SUPPLY IN DELAWARE

For the purpose of this report a public water supply is considered to be a supply serving incorporated towns and cities, and/or unincorporated housing developments, or resort areas, whether owned by the community (municipal) or by a private corporation or individual.

There are 43 such supplies throughout the State of Delaware if the four small systems serving beach areas in Kent and Sussex County are included. Table 16-1 lists these supplies. A review of the table shows that 27 are municipally-owned and operated while 16 are privately-owned. It also shows that 38 of these supplies are secured from ground water. The four surface supplies, however, serve 56.6 percent of the population using public water systems, and one of these serves 49 percent. The public water systems served 311,287 people, or 68 percent of the estimated 458,000 persons living in the State in 1958.

16.02 PRESENT (1958) WATER REQUIREMENTS OF PUBLIC WATER SUPPLIES

In order to determine water usage by the public water systems of the State, representatives of the State Board of Health visited each community or privately-owned system and interviewed a responsible person. Some of the data secured from these interviews is included in Table 16-1.

a. New Castle County requirements. As shown in Table 16-1, there are 15 public water supplies in New Castle County. Included are Wilmington which serves 49 percent of the people who depend on public systems; five other incorporated communities; and the extensive suburban area located in the upper one-third of New Castle County. This latter area has been one of the fastest developing sections of the eastern seaboard and includes approximately 300 unincorporated housing developments. The majority of these developments are served by two privately-owned public water supplies. One of these supplies is the most extensive ground-water system in Delaware, utilizing more than 40 wells located in three different hundreds. (In Delaware a "hundred" is a political subdivision somewhat similar to a township in other states.)

Assuming that the maximum daily demand for all supplies occurs simultaneously, the per capita demand is 206 gallons. The 250 gallons per capita demand of the users of surface water is more than double that (110 gallons) of the ground-water supplies. This can be explained by the fact that the biggest surface supply, Wilmington, serves considerable industry, while most of the ground-water systems are, for the most part, domestic water suppliers.

b. Kent County requirements. All the Kent County public water systems are served from wells. The tables include three beach-area [illegible]

supplies, Kitts Hummock, Pickering Beach, and South Bowers, which are used principally during summer months. The maximum daily per capita demand is 144 gallons, and the average daily demand is 117 gallons.

c. Sussex County requirements. As in Kent County, all the water supplies in Sussex are ground-water systems. Two small systems, Slaughter Beach and Sussex Shores, are used mostly during the summer. In addition, the supplies at Bethany Beach, Lewes, and Rehoboth Beach have extreme variations in demand between winter and summer because of the influx of large numbers of summer vacationists.

The maximum daily per capita demand for Sussex County is 204 gallons, and the average demand is 102 gallons daily per capita.

d. Rural area requirements. For purposes of estimation it is assumed that each person not served by a public water system uses 50 gallons of water per day. Assuming that this population is approximately 130,000, the daily demand is 6.5 million gallons. All of this can be assumed to be supplied from wells.

e. State-wide requirements. In summation, the domestic demands of the State are shown in Table 16-2.

16.03 THE SOURCE OF WATER SUPPLY FOR MILITARY INSTALLATIONS AND STATE INSTITUTIONS

a. Military installations. The major military installations in Delaware include the Dover Air Force Base, the New Castle Air Base, Fort Miles, and the Army camp at Bethany Beach. All these sites employ ground water as their sources. Although these installations were not visited to determine daily usage of water, it is estimated that the total maximum daily demand of all four installations is from 1 to 2 million gallons. This estimate is based on a population of 10,000 and a daily per capita consumption of 150 gallons.

b. State institutions. Delaware institutions include the Emily P. Bissell Hospital near Marshalltown, the State Hospital at Farnhurst, the Governor Bacon Health Center at Delaware City, the Hospital for the Mentally Retarded at Stockley, the New Castle County Correctional Institution at Greenbank, the Sussex County Correctional Institution at Georgetown, the State Welfare Home and Hospital for the Chronically Ill at Smyrna, and the Delaware State College at Dover. All of these, except the Bissell Hospital, secure their water from wells. The Bissell Hospital supply is a small stream. The maximum daily usage at the Bissell Hospital is approximately 100,000 gallons. It is estimated that 750,000 to 1 million gallons per day are required to supply these facilities.

16.04 THE SOURCE OF WATER SUPPLY FOR COMMERCIAL AND INDUSTRIAL USE NOT OBTAINED FROM PUBLIC SUPPLIES

Late in 1957 representatives of the State Water Pollution Commission made a survey of all industrial and commercial establishments. Included was the source of the water serving the establishment and the rated capacity of pumping facilities. Approximately 230 establishments

maintained ground-water sources, and 50 had surface supplies as their source. The ground-water sources had a combined pumping capacity of about 61,000 gallons per minute. On the other hand, the users of surface supplies had a combined pumping capacity of over 800,000 gallons per minute. The combined capacity of all 280 establishments is approximately 1.25 billion gallons per day.

16.05 ESTIMATES OF FUTURE REQUIREMENTS OF PUBLIC WATER SUPPLIES

In Table 16-4 the estimated needs for public water systems and domestic rural supplies are given for the year 2010. The following assumptions were used in making this estimate:

a. That the Wilmington Water Department would be serving 200,000 persons: 140,000 within the city limits, and 60,000 in Brandywine Hundred and other outlying areas.

b. That all the area north of the Chesapeake and Delaware Canal would be so highly developed that all the population would be served by public water systems.

c. Per capita water consumption was estimated as 250 gallons for the city system, 125 gallons for other public systems, and 50 gallons for rural uses.

It is estimated that approximately 50 percent of the population served by public water systems will be supplied from surface sources. Assuming that 700,000 persons are thus supplied, the daily surface water demand would be about 135 million gallons. This means that ground sources will be called upon to supply approximately 125 million gallons per day for domestic water needs in the year 2010 in Delaware.

16.06 GROUND WATER QUALITY

Domestic and industrial water supplies in Delaware are derived from both ground and surface sources. The northern portion of the State is dependent upon surface supply while the much larger southern part of the State depends upon ground-water sources.

These surface-water sources are soft, neutral, and require little or no chemical treatment to remove such undesirable constituents as iron. An exception to this rule would be water used for special industrial processing. Water quality data covering a period of many years exist for these surface sources, specifically for the Wilmington water supply.

In order to evaluate ground-water resources it is assumed that the safe yield must be determined, and this yield is largely dependent upon the recharge capacity of the aquifer. It is equally important to a water-resources evaluation to determine the economics involved in obtaining water of satisfactory quality. Pumping costs, reservoir costs, and length of distribution systems are integral parts of the total water picture whether the source be surface or ground. Consequently, to get a full evaluation of the ground-water resources we must of necessity consider not only the initial construction cost, the recharge capacity, and the pumping

costs, but also whether further treatment of these ground waters is needed before distribution for use.

It is known that many of the ground-water supplies in Delaware are corrosive and of high iron content. However, no formal procedure of analysis exists to obtain data with regard to the quality of these ground waters.

The Water Pollution Commission has conducted 156 well-water analyses during the past eight years, primarily to obtain a general analytical knowledge of the constituents of these sources. Of this total, 141 wells were analyzed for iron, and depth information is abailable for 83 of them. However, pH tests were performed on all 156 wells, with depth information being available for 95. (Note: pH is a measure of the corrosive quality of water. It is measured on a scale divided into 14 parts. A neutral quality is indicated by a reading of 7; descending the scale from 7 to 0 indicates increasing acidity, while ascending the scale from 7 to 14 indicates increasing alkalinity.)

A summary of the ground water analyses made during the last eight years is presented in Tables 16-5, 16-6, and 16-7. It is evident from Table 16-5 that the pH reaction is an important issue in Delaware. The table shows a high percentage of waters containing pH values less than 6.0 in each of the counties. It is also interesting to note that as we move downstate from New Castle County into Kent and Sussex Counties a greater percentage of high acid content water exists in the shallower wells. This pattern of low pH was evident in all wells whether or not the depths were recorded.

In Table 16-6, which shows the iron content of 141 random well samples, it is readily observed that the undesirable iron concentrations are a common occurrence. In each county a large percentage of wells contain iron concentrations exceeding the acceptable maximum of 0.3 ppm established by the U.S. Public Health Service Drinking Water Standards. It is also significant in this table that a relatively high percentage of the wells contain iron in excess of 4.0 ppm.

In Table 16-7, which expresses the correlation of well depth and iron content, it is evident that a high concentration of iron exists in the shallow wells of both Kent and Sussex Counties. Further, wells less than 75 feet deep constitute the greatest number of wells from which samples were collected and analysed, and, in all probability, represent the greatest area of withdrawal.

16.07 SUMMARY

From sections 16.04 and 16.05 it is apparent that demends for ground water for municipalities, industry and commerce, and institutions for the year 2010 may reach 700 million gallons per day. This does not include any estimates of agricultural uses of water and present-day trends indicate that irrigation alone requires enormous quantities.

The present use of surface water by industry, mostly for cooling purposes, is enormous. By 2010 this usage, at the minimum, will probably

have increased several times.

It is reasonably evident from the above that Delaware possesses ground water of such quality that a careful evaluation with respect to water resources planning is required. Pumping of ground water directly to the user without intermediate treatment, as is often the case with ground water supplies, is not fully applicable to the conditions found in Delaware. Our ground waters show a progressive pattern of low corrosive $_{p}H$ and high iron content. These conditions dictate an increased cost for ground water over and above similar supplies requiring no removal of iron or adjustment of $_{p}H$.

Therefore, the State of Delaware should take at least two steps toward conserving existing sources and obtaining additional ones. These are:

a. The early enactment of a strong water-use law which will adequately control all users of surface and ground water of the State.

b. Aggressive and positive action toward insuring a just share for Delaware in waters of the Delaware River, the Brandywine, and all other possible sources.

TABLE 16-1

WATER CONSUMPTION (1958) BY PUBLIC WATER SUPPLIES IN DELAWARE

	Name of Town or Water Company	Type of Ownership	Water Source	Population Served	DAILY CONSUMPTION AVERAGE Gallons (Thousands)	AVERAGE Gallons per Capita	MAXIMUM Gallons (Thousands)	MAXIMUM Gallons per Capita
	New Castle County							
1	Arden Water Co.	Private	Surface	2,614	285	109	385	147
2	Artesian Water Co.	Private	Ground	49,505	3,513	70	5,670	120
3	Cantwell Water Co.	Private	Ground	80	4	50	6	75
4	Crestfield Water Co.	Private	Ground	60	3	50	5	80
5	Delaware City Water Co.	Private	Ground	1,000	85	85	100	100
6	Delaware Water Co.	Private	Surface	1,200	68	75	120	100
7	Middletown	Municipal	Ground	2,000	120	60	150	75
8	Newark	Municipal	Ground	12,000	950	79	1,193	99
9	New Castle	Municipal	Ground	5,500	600	120	900	162
10	New Castle County Water Co.	Private	Ground	7,000	300	43	500	71
11	Newport	Municipal	Ground	1,210	135	112	148	122
12	North Star Water Co.	Private	Ground	150	15	100	19	127
13	Townsend	Municipal	Ground	450	29	64	38*	85
14	Wilmington	Municipal	Surface	153,500	25,000	163	39,000	255
15	Wilmington Suburban Water Corp.	Private	Surface	18,950	3,110	165	4,500	238
	Totals			255,219	34,347		52,971	

* Estimated

TABLE 16-1 (Continued)

WATER CONSUMPTION (1958) BY PUBLIC WATER SUPPLIES IN DELAWARE

	Name of Town or Water Company	Type of Ownership	Water Source	Population Served	DAILY CONSUMPTION AVERAGE Gallons (Thousands)	DAILY CONSUMPTION AVERAGE Gallons per Capita	DAILY CONSUMPTION MAXIMUM Gallons (Thousands)	DAILY CONSUMPTION MAXIMUM Gallons per Capita
	Kent County							
16	Camden-Wyoming	Municipal	Ground	2,000	140	70	280	140
17	Camden Park Water Co.	Private	Ground	292	14	48	24	81
18	Clayton	Municipal	Ground	1,000	30	30	50	50
19	Dover	Municipal	Ground	12,250	1,226		1,867	152
20	Felton	Municipal	Ground	400			120	240
21	Frederica	Municipal	Ground	800	192	240	240	300
22	Harrington	Municipal	Ground	2,400	100	42	125	52
23	Magnolia	Municipal	Ground	325	26	80	35	107
24	Milford	Municipal	Ground	6,000	558	92	750	128
25	Smyrna	Municipal	Ground	3,000	385	66	650	198
	Totals			28,467	2,671		4,141	

TABLE 16-1 (Continued)

WATER CONSUMPTION (1958) BY PUBLIC WATER SUPPLIES IN DELAWARE

	Name of Town or Water Company	Type of Ownership	Water Source	Population Served	DAILY CONSUMPTION AVERAGE Gallons (Thousands)	AVERAGE Gallons per Capita	MAXIMUM Gallons (Thousands)	MAXIMUM Gallons per Capita
	Sussex County							
26	Bethany Beach	Municipal	Ground	250	16.5	165	180	50
27	Bridgeville	Municipal	Ground	1,450	109		145*	100
28	Delmar	Municipal	Ground	2,900	300	103	700	240
29	Frankford	Municipal	Ground	600	30	50	39*	65
30	Georgetown Water & Supply Co.	Private	Ground	2,900	200	69	409	140
31	Greenwood	Municipal	Ground	800	75	94	100	125
32	Laurel	Municipal	Ground	2,800	150	53	225*	80
33	Lewes	Municipal	Ground	3,500	940	267	2,000	570
34	Millsboro	Municipal	Ground	604	32	52	43*	71
35	Milton	Municipal	Ground	1,500	115	75	140	93
36	Rehoboth Beach	Municipal	Ground	3,000	250	83	888	
37	Seaford	Municipal	Ground	5,500	410	75	550*	100
38	Selbyville	Municipal	Ground	1,450	125	86	135	93
39	Sussex Shores Water Co.	Private	Ground	50	4		5	
40	Slaughter Beach	Private	Ground	150	7.5		25	
	Totals			27,454	2,764		5,384	
	* Estimated							
	County Totals	New Castle		255,219	34,347		52,971	
		Kent		28,467	2,671		4,141	
		Sussex		27,454	2,764		5,384	
	State Totals			311,140	39,782		62,496	
		Surface		176,264	28,463		44,005	
		Ground		134,876	11,319		18,491	

TABLE 16-2

SUMMATION OF WATER DEMANDS BY PUBLIC SUPPLIES
AND RURAL DOMESTIC REQUIREMENTS

	Consumption in Gallons per day		Consumption in Gallons per minute	
	Public Water Supplies	Rural	Public Water Supplies	Rural
New Castle County	52,737,500	1,930,000	36,500	1,340
Kent County	4,140,200	1,721,650	2,870	1,195
Sussex County	5,383,900	2,860,000	3,740	1,980
Totals	62,261,600	6,511,650	43,110	4,515
Total Public and Rural	68,773,250		47,625	

TABLE 16-3

ESTIMATE OF POPULATION FOR DELAWARE 1958-2060

AREA	1958	1965	1980	2010	2060
Wilmington	115,357	117,000	120,000	140,000	150,000
Unincorporated area of New Castle County north of Canal.	148,443	250,000	374,200	698,400	1,888,600
Rural area north of Canal.	25,000				
Unincorporated area of New Castle County south of Canal.	13,600	31,000	37,000	74,000	110,000
New Castle County Totals	302,400	398,000	531,200	912,400	2,148,600
Rural area	34,443	36,000	38,000	42,000	50,000
Served by public water systems.	28.467	86,200	131,000	232,500	560,300
Kent County Totals	62 910	122,200	169,000	274,500	610,300
Rural area	57,200	60,700	62,000	77,000	100,000
Served by public water systems	27,400	50,000	94,500	162,500	387,200
Sussex County Totals	84,600	110,700	156,500	239,500	487,200
State-wide Totals	458,000	631,000	856,700	1,426,400	3,352,100

TABLE 16-4

COMPARISON OF MUNICIPAL WATER SUPPLY REQUIREMENTS
FOR THE YEARS 1958 AND 2010

AREA	Population Served 2010	Per Capita Demand (Gallons)	DAILY CONSUMPTION (Thousands of Gallons) 2010 Public Water Systems	2010 Rural	1958 Public Water Systems	1958 Rural
New Castle County						
Wilmington	200,000	250	50,000		39,000	
Other public systems	638,000	125	79,800		13,737	
Rural	74,000	50		3,700		1,930
Kent County						
Public systems	232,500	125	29,100		4,140	
Rural	42,000	50		2,100		1,721
Sussex County						
Public systems	162,500	125	20,300		5,384	
Rural	77,000	50		3,850		2,860
Subtotals			179,200	9,650	62,261	6,511
Total for State	1,426,000		188,850		68,772	

TABLE 16-5

PART A

CORRELATION OF WELL DEPTH WITH pH*

	New Castle			Kent			Sussex		
Number of Wells	16			59			20		
Depth Range in Feet	0-30	31-75	Over 75	0-30	31-75	Over 75	0-30	31-75	Over 75
pH over 6.5	-	2	2	3	5	13	-	2	2
pH 6.0-6.5	-	-	3	6	9	-	2	3	2
pH 5.5-6.0	1	-	2	8	6	-	-	2	3
pH 5.0-5.5	-	2	3	1	5	-	3	-	-
pH 4.5-5.0	-	1	-	3	-	-	-	-	-
pH 4.0-4.5	-	-	-	-	-	-	1	-	-
% less than pH 6.0	-	60.0	50.0	58.2	44.0	0	66.7	28.7	43.0

* A total of 95 wells of known depth.

PART B

pH VALUES OF 61 WELLS OF UNKNOWN DEPTH

	New Castle	Kent	Sussex
Number of Wells	7	33	21
pH over 6.5	3	5	7
pH 6.0-6.5	3	10	6
pH 5.5-6.0	-	9	6
pH 5.0-5.5	-	8	1
pH 4.5-5.0	-	-	-
pH 4.0-4.5	-	1	1
% less than pH 6.0	14.3	54.6	38.0

TABLE 16-6

IRON CONTENT OF 141 RANDOM WELLS
IN DELAWARE

	New Castle	Kent	Sussex
Total number analyzed	17	89	35
Average iron content, ppm	2.94	3.33	5.81
Iron content			
0 - 0.3 ppm	6	22	8
0.3 - 1.0 ppm	2	18	3
1 - 2 ppm	4	13	6
2 - 3 ppm	0	9	3
3 - 4 ppm	0	5	3
4 - 5 ppm	3	7	0
5 - 6 ppm	0	7	2
Iron content more than 6 ppm	2	8	10
Wells with iron content more than 4 ppm	5	23	13
Percent of wells with iron more than 4 ppm	29.4	25.8	37.1
Percent of wells with iron content in excess of 0.3 ppm standard	65.0	76.0	77.0

TABLE 16-7

CORRELATION OF WELL DEPTH WITH IRON CONTENT*

	New Castle			Kent			Sussex		
Number of Wells	10			54			19		
Depth Range in Feet	0-30	31-75	Over 75	0-30	31-75	Over 75	0-30	31-75	Over 75
Iron content									
0 - 0.3 ppm	-	1	2	5	4	4	2	-	-
0 - 1.0 ppm	-	1	-	5	3	1	-	-	1
1 - 2 ppm	-	1	1	1	4	3	-	3	1
2 - 3 ppm	-	-	-	2	4	-	1	-	1
3 - 4 ppm	-	-	-	-	2	1	-	-	2
4 - 5 ppm	-	1	1	3	2	-	-	-	-
5 - 6 ppm	-	-	-	1	3	1	-	-	-
Iron content more than 6 ppm	1	-	1	3	1	1	2	4	2
TOTAL WELLS	1	4	5	20	23	11	5	7	7
Percent of wells over 0.3 ppm	-	75.0	60.0	75.0	74.0	63.5	60.0	100	100
Percent of wells over 4.0 ppm	-	25.0	40.0	35.0	30.4	18.0	40.0	57.2	28.6

* A total of 83 random wells for which depth and iron content are known

SECTION XVII

STATE SOIL CONSERVATION COMMISSION

17.01 INTRODUCTION

In the preparation of this report, the State Soil Conservation Commission assumes, without question, that agriculture will continue to have an important and permanent place in the future economy of Delaware. Actually, this report goes even further, in that it indicates the possibility of future intensification of agricultural endeavors to a scale rivaling the tremendous advances that can be expected from industry in the years ahead.

a. Increase in size of farms. Extensive data, gathered for many years by the Agricultural Economics Department of the University of Delaware, accurately portrays both the present-day situation of Delaware agriculture and the many changes which have occurred during the past 50 or more years. The number of farms and the number of acres of farmland being cropped have slowly, but steadily decreased. At the same time, the average Delaware farm has become appreciably larger. During the twenties the average farm size was 93 acres. By 1957. the average size had increased to 129 acres.

(1) Increase in truck crops. Of even more importance, the acreage of truck crops has also been increasing in spite of the overall decline in the use of croplands. For example, within the past 10 years, the acreage of white potatoes being grown in Delaware has been tripled. The respective acreages of asparagus, lima beans, snap beans, and green peas have doubled during the same period, and this has occurred in the face of our present agricultural surpluses. Our 1952-1955 average total of acres of field corn harvested was 172,000 acres. This is 36,000 more than the average acres of field corn harvested during the 1944-1948 period. The increase in soybeans harvested is even more impressive. During 1956, approximately 150,000 acres of these were harvested, as compared with 34,000 acres of soybeans which were harvested in 1944.

(2) Increase in annual cash farm income. Acreage alone, moreover, does not tell the full story. In the face of decreasing acres of cropland being harvested, gross income from crops increased spectacularly. One of the most recent releases from the University of Delaware, Department of Agricultural Economics, shows the gross cash farm income for the ten-year period - 1948-1957. For the first three years, 1948-1950, the average total annual cash farm income from crops was $17,062,000, and for the same years the average annual total cash farm income was $98,832,000. By the last three years of that decade, 1955-1957, the average annual cash income from crops rose to $29,268,000, while the average annual total cash farm income rose to $108,254,000. These figures show that crops accounted for all of the gain in average

annual total cash farm income, and, in addition, even overcame a significant decrease of annual cash farm income from livestock and related products.

b. Effect of water control. Water management must be given credit for part of this splendid achievement. The 1,632 miles of individual and group drainageways constructed and improved during that decade certainly played an important role. So did the irrigation work which expanded so rapidly during the last few years. As the pressure of increasing population develops in the years to come, it must be expected that water management will become even more significant.

c. Potentially permanent farm land. Delaware is fortunate in having a very high percentage of land that is capable of being cropped forever. In fact, it is one of the foremost states in this respect. That land is situated almost in the heart of the concentration of population in the New York City, Philadelphia, Wilmington, Baltimore, and Washington zone. It is only logical to assume that in the future this land will become quite valuable and that it will be called upon to bear a heavy load in helping feed our new millions of people to come. To do that will require almost perfect freedom from damaging excess surface waters and almost unbelievable quantities of water to supplement our natural rain fall. It is hoped that this report will serve the purpose of indicating how great this need for water for crop production could become.

17.02 PRESENT STREAM FLOWS AND SEDIMENT LOAD DUE TO EROSION

A review of available material for the streams of the State of Delaware, especially with regard to sediment load carried in the flow due to erosion, reveals very little definite and conclusive data. There is no question that water and wind erosion are causing a loss of soil from agricultural lands, and this loss definitely helps make up the sediment load in the various streams and waterways of the State. It is equally true that ditch banks, stream banks, highway cuts and fills, highway road gutters, miscellaneous construction areas, and other sparsely vegetated areas are subject to erosion and are also contributing to the sediment loads in Delaware streams. In some locations, particularly in the northern part of the State, it is probable that the latter type of erosion is responsible for most of the sediment load.

So far as the Commission can determine, there have been no studies made in Delaware to fix the sources of the sediment loads in the various waterways of the State. It is true that sediment studies for the Brandywine Creek have been made, but these reflect total sediment loads and cannot be used as a source of material for tracing the sediment load due to erosion. Of course, it may be said that when all forms of erosion are included, the total sediment load of the Brandywine, except for certain waste materials, consists of products of erosion. Since most of that material originates outside of Delaware, however, even the Brandywine data become less valuable for use within the State.

The United States Soil Conservation Service is well along with an erosion survey of Delaware. Already it is possible to calculate the tons of topsoil that have been lost from thousands of acres of Delaware farmland. Where that soil went, though, cannot be determined. Some of it moved only to adjacent hedgerows or wooded areas. Some helped fill local depressions or nearby ponds. Much of it was deposited on flatter slopes or on adjacent marshes. Some filled highway ditches and had to be excavated and hauled away. Part of it reached the streams and became sediment load. Soil types, slopes, land uses, agricultural practices, general terrain, rainfall intensity, drainage pattern, and still other factors affect the development of sediment loads. With so many variables and practically no research data, the inevitable conclusion is that it is not possible to furnish adequate data for this part of the report. For further reference, see the report of the U.S. Department of the Interior, Geological Survey, Water Resources Division, entitled, "The Trend of Suspended-Sediment Discharge of the Brandywine Creek at Wilmington, Delaware, 1947-1955," by H. P. Guy.

17.03 PRESENT AGRICULTURAL PRACTICES AND THEIR EFFECTS UPON DRAINAGE

In studying present land uses, especially with regards to the present agriculture practices and their effects upon drainage, considerable data are available. A chart of land use for each of the counties and a list of applied agricultural soil conservation practices for the entire State is included in this report as Table 17-1. In addition to those soil conservation practices listed, which are the ones established with assistance from the County Soil Conservation Districts, other practices have been put into effect through efforts of the Extension Service and also the Agricultural Conservation Program. Complete report data are not available from those two sources, but their accomplishments have been outstanding. For example, during the four-year period 1954 through 1957, under the ACP program, 6,352 acres had permanent cover developed for soil protection or land-use adjustment, 101,582 acres had lime applied on cropland to permit use of conserving crops, 137,029 acres had vegetative cover established to provide winter protection from erosion, and 5,320 acres had cover established to protect cropland during the course of the particular crop year.

Unfortunately, however, research and conclusive data as to the effects of land uses and agricultural practices upon drainage seem to be completely lacking. Thousands of acres of certain kinds of Delaware lands have had soil conservation drainage facilities installed, which have resulted in the development of good to excellent drainage. Other thousands of acres with fair to poor drainage are still in need of similar practices. The nature of the soil, the topography, and various other factors are the basic causes for inadequate drainage. On lands which are inherently well drained, agricultural practices may have an appreciable effect upon runoff, but their effects upon drainage are relatively insignificant. On lands that are basically imperfectly or poorly drained, only the application of the necessary drainage measures can bring about the improvement of drainage conditions. Soils with uncorrected drainage problems often can be utilized for trees, and sometimes grasses, even where field or truck crops cannot be grown successfully. This less intensive land use, however, in no way constitutes a means of improving a drainage problem. It merely presents one means of living with it.

TABLE 17-1

TOTAL SOIL CONSERVATION ACCOMPLISHMENTS
NEW CASTLE, KENT, & SUSSEX SOIL CONSERVATION DISTRICTS

PRACTICES APPLIED--INDIVIDUAL FARMS	UNIT	TO DATE
Cropland - Conservation Crop Rotations	acres	277,330
Cropland - Contour Farming	acres	3,659
Cropland - Cover Cropping	acres	145,653
Cropland - Stubble Mulching	acres	159,656
Cropland - Strip Cropping	acres	3,157
Grassland - Establishing Permanent Hay	acres	4,377
Grassland - Pasture Improvement	acres	22,675
Grassland - Pasture Planting	acres	15,466
Grassland - Rotation Grazing	acres	21,443
Woodland - Improvement Cutting	acres	13,625
Woodland - Tree Planting	acres	1,284
Woodland - Protection	acres	15,859
Wildlife - Fish Pond Improvement	no.	76
Wildlife - Hedgerow Planting	rods	20,556
Wildlife - Area Improvement	acres	4,418
Wildlife - Borders	acres	455
Wildlife - Marsh Improvement	acres	614
Drainage, all types	acres	46,122
Ditch Construction	mi.	1,320
Ditch Construction	cu. yds.	4,658,468
Tile Drains	l.f.	115,718
Land Clearing	acres	5,526
Obstruction Removal	acres	3,049
Pond Construction	no.	218
Sprinkler Irrigation Systems	no.	73
Sprinkler Irrigation Systems	acres	5,196
Land Smoothing	acres	170
Spoil Leveling	cu. yd.	3,005,605
Diversion Terraces	mi.	13
Sub-Soiling	acres	1,202
PRACTICES APPLIED-DRAINAGE GROUPS		
Ditch Construction	mi.	312
Ditch Construction	cu. yd.	2,254,332
Spoil Leveling	cu. yd.	1,016,990
Obstruction Removal	acres	852
Culverts	no.	280

From the above, it is possible to draw at least two somewhat different conclusions. The first might be that because special drainage practices have not yet been established on all of the imperfectly and poorly-drained lands of the State, present agricultural practices are still somewhat adversely affecting drainage. The other, and possibly more rational conclusion, is that present agricultural practices, as such, have practically no effect upon drainage. Where agricultural practices on imperfectly and poorly-drained soils include the use and maintenance of adequate drainage measures, including proper ditching, land leveling, obstruction removal, spoil leveling, proper plowing, proper cultivating and other necessary things, a minimum of drainage problems remain. Where such practices are not in effect, drainage problems in varying degrees will continue to prevail.

17.04 EFFECTS OF SOIL CONSERVATION TECHNIQUES ON LOW AND HIGH STREAM FLOW

There is apparently no research data to show the effects of soil conservation techniques on low and high stream flow in Delaware. An approach to such data is possibly the conclusion reached by H. P. Guy in his report on the Brandywine Creek, which was referred to in Section 17.02, b. In that report, the possibility is indicated that sediment damages may be considerably reduced by virtue of the upstream application of soil conservation practices and techniques. That report, however, does not go on to develop a conclusion as to the possible change in runoff to correspond with the sediment reduction.

On a national basis, of course, there is an abundance of available data. Studies conducted at various research stations all over the country for many years have established definite relations between runoff, slope, soil type, land use, cover, and soil conservation techniques. In addition, research has been done by entire watersheds to investigate those same relations. Generally, soil conservation techniques have been found to diminish and slow up runoff. Under certain conditions, however, particularly when entire watersheds or parts of watersheds are considered, it is possible for flood peaks to reach high levels, even after soil conservation practices have been completely effective. This is the exception, of course, but it is definitely possible.

To go one step further, it must be recognized that the above applies to soil conservation techniques adapted for upstream, soil-and water-retaining purposes. The soil conservation techniques of drainage can have an opposite effect, particularly in the early stages of development.

The prime purpose of drainage, naturally, is to remove excess surface and subsurface waters of a damaging nature. Byproducts of draining include water management, development of improved field arrangements, integration with good cropping practices to increase water-holding capacity of the soil, and, under certain conditions, even supplementary irrigation.

Impoundment of water is encouraged during the dry seasons in the same ditches and drains that are used to remove excess water during flood periods. This is readily accomplished by means of extremely simple

structures located in the small headwater ditches, wherever they may be located. With this system, every landowner can become a manager of all the surface water on his own farm, except where his land borders or is traversed by a major tributary or stream. The possibilities of such management are of extreme importance when considered in the over-all water situation. In areas where modern drainage and water management is practiced, it is entirely conceivable that the outlet ditches, and even some of the small tributaries, will become dry during a large part of the summer season, except in periods of unusually heavy rainfall.

Within Delaware, excluding the marsh lands, there are approximately 327,000 acres of imperfectly and poorly-drained soils. Of these, approximately 21,000 acres are in New Castle County, 100,000 acres in Kent County, and 206,000 acres in Sussex County. The above acreages include both cropland and woodland. Even though these figures indicate a drainage problem for at least 25 percent of the State, they do not indicate the size of the potential drainage problem in its broadest application. The areas of imperfectly and poorly-drained soils do not occur in one big block or even in many big blocks. Instead, they are invariably intermingled with areas of well-drained soils. As a result, the areas served by drainage operations often include high percentages of what we class as well-drained or at least reasonably well-drained soil. It would not be reasonable to expect an exact estimate of the overall state wide ratio between better-drained and poorly-drained soils in all of the potential watersheds where drainage and water management may eventually be practiced, but experience to date would indicate that at least half of the total areas, which might be encompassed, would be constituted of better-drained soils.

Without research data to guide us and with so much control potentially in the hands of individual landowners, we are hardly in a position to draw conclusions as to the effect of soil conservation techniques on low and high stream flows. Under some conditions, the flows might be stabilized, thereby reducing some of our highest flows and augmenting the lowest flows. Conceivably, soil conservation techniques might be expected to increase the transfer of surface water to ground water. In some locations this would decrease the total amount of water that runs off into the streams. For other areas, where ground water recharging of the stream occurs, this difference might be very small. We again have too many variables. Our answer, therefore, must be indefinite.

17.05 PROBLEM OF FLOOD CONTROL AND UTILIZATION OF WATER

In reviewing the problem of flood control and the utilization of water the following must be considered: erosion conditions, flood and sediment damages, the areas of contribution, and the loss of agriculture as the result of inundation.

a. Erosion conditions. To a large degree, available information pertinent to this subject was covered in the discussion of the sediment load due to erosion (Par. 1702). We are quite sure that erosion, particularly of the accelerated or gully type, contributes substantially to flood development and to the creation of heavier sediment loads in the state waterways. As reported above, a large area of the State, more

than 670,000 acres of the agricultural lands, in fact, has been mapped within the past 15 years by the Soil Conservation Service. We have no figures at all, however, to measure the erosion that has been and is still occurring on ditch banks, stream banks, construction areas, urban areas, etc., outside of the agricultural areas. We lack even the data necessary to show what happened to the material which conservation surveys show has been removed from the thousands of fields that have been mapped. General information can be secured from the Soil Conservation Service which will show that moderate erosion has occurred on most of the agricultural lands of Delaware. It is doubted, however, that this information would be of sufficient value to warrant the effort.

b. Flood and sediment damages and areas of contribution. There are three distinct types of flooding which occur in Delaware. The Brandywine Creek represents one type of flooding. This, and other major streams throughout the State, are well defined and normally flow within their established banks. During high intensity storms, when exceptionally heavy runoff occurs, however, the stream flow exceeds the capacity of the particular waterway and the lands immediately adjacent thereto become flooded. A second type of flooding occurs in relatively flat portions of the Coastal Plain areas of the State, where drainage and related flood control measures have not been put into operation. The third type of flooding is some combination of the first two.

The hydrologic studies for the Brandywine Creek which were carried on for nearly 10 years, and the more recent studies of the Brandywine Watershed in connection with the development of a work plan for flood prevention, have indicated relatively small amounts of flood and sediment damage to land that has remained in agriculture. Generally speaking, we believe that this situation exists along most streams in the northern part of the State. It is true, of course, that these same streams at flood stage cause considerable damage to residential and industrial developments, and, in some cases, to wildlife and recreation areas. The Commission assumes that the examination of these latter damages is not its responsibility in the preparation of this report.

Considering the second type of flooding, an intensive study of flood water damage and sediment damage has been recently completed for the Upper Nanticoke River Watershed, which includes approximately 120,000 acres in Kent and Sussex Counties. The results of that study are included in the work plan for the Upper Nanticoke River Watershed. The findings as to flood water damages and sediment damages, as shown in this plan, are more or less typical for large areas of the Coastal Plain soils of the State.

For the third type of flooding, it is more difficult to select an example. There will undoubtedly be areas of the Upper Coastal Plain and the lower Piedmont soils where the flooding should be properly classed as a combination of the first two types. In other locations, tidal flooding might cause complications that could cause the problem to be classified as the third type. In this connection, tidal flooding has for the most part been disregarded in the consideration of the flooding problem on the basis that most lands subject to that type of flooding are possibly best suited to wildlife uses, and as such, are not considered to be agricultural lands. The aggravation of stream flooding resulting from tidal flooding,

however, must be taken into account where this occurs.

Considering the areas of contribution, much of the flooding in Delaware is caused by runoff due to direct precipitation on lands within the State. In northern New Castle County this is not always the case, since the principal streams and their accompanying flood problems originate in nearby Maryland and Pennsylvania. Ninety percent, for example, of the flood-producing area of the Brandywine is outside of Delaware. The watershed of the Delaware River above the mouth of the Christiana River is not considered, in this report, to be an area of contribution on the grounds that the Delaware River probably causes very little damage to agricultural lands. By the same token, since sediment deposit damage to croplands is not significant, and because in some instances sediment deposits can be actually beneficial, sources of such sediment are not being considered in this report in connection with this particular problem.

c. Land lost to agriculture due to inundation. It is difficult, or even impossible, to establish reasonably exact figures for the average annual number of acres of agricultural lands that are actually inundated in Delaware. It is also unlikely that accurate figures can be established to show the acreage that could be agricultural land, provided that regular or periodic flooding could be eliminated. Instead, the loss to agriculture due to inundation must be measured in terms of crop failures, crop reductions, minor sediment damage, and in occasional instances, cost of removing flood debris. Furthermore, the losses due to inundation cannot be satisfactorily separated from the losses due to lack of drainage. The two problems are much too closely integrated to permit such separation.

Since the agricultural losses due to inundation seem to prevail in part of the Coastal Plain area of the State, we again refer to page 39 of the Upper Nanticoke River Watershed Work Plan as being typical of that problem area. We realize that agricultural losses, as such, were not established and shown as part of that study, but equally useful data were developed from the determination of the benefits that might be expected from the prevention of flooding. Actually, there can be an appreciable difference between the total damages caused by flooding and the benefits that might be achieved by the practical prevention of such flooding. Because of other factors, principally the close integration of drainage benefits, we do not consider the differences significant. We believe, therefore, that figures comparable to those developed in this Work Plan may apply to approximately half of the agricultural land area of the State.

17.06 DETERMINATION OF PRESENT AGRICULTURAL WATER REQUIREMENTS

In order to determine future water needs we must examine current agricultural requirements for domestic farm use, including irrigation, and the present source of water to meet the current needs.

a. Present agricultural demands for domestic use. In 1955 the Delaware Water Resources Study Committee published a preliminary

report with the assistance of most of the affected state and federal agencies. Since this represented the best combined thinking of all concerned, and since that report is relatively new, the Commission feels that it has no choice except to show the combined domestic and farm water requirements which were estimated in that report. These amount to approximately 5 million gallons per day.

b. Present agricultural demands for irrigation. Figures obtained by careful surveys through efforts of the University of Delaware indicate that in 1954, 4,640 acres were irrigated in Delaware. In 1955, the irrigated acreage rose to 9,068 and then fell back to 4,022 acres in 1956. Another sharp rise occurred during 1957, when an all-time high of 14,269 acres were irrigated. This did not include the acreage under irrigation by commercial nurseries throughout the State.

Apparently about 4 inches of water was the average application for the entire 14,269 acres. If these figures are correct, almost 1,554 million gallons of water were used for irrigation by farmers during 1957. Data are lacking to show the actual timing of all of the irrigations, so certain assumptions must be made. One is that the applications were made during 30 twelve-hour average days; the second is that the applications were made during 40 twelve-hour days; and a third is that the total irrigation season lasted 60 days.

On the basis of the third assumption, approximately 26 million gallons per day was the average total farm use for the most critical 2-month period. On the basis of the first assumption, nearly 52 million gallons per day were used during each of the pumping days. On the basis of the second assumption, about 39 million gallons were applied during each pumping day. Taking the largest figure of 52 million gallons per day for 12-hour days, it is apparent that the average pumping rate during application amounted to something over 72,000 gallons per minute for the entire State.

Actually, the pattern of irrigation does not follow the average figures. It is quite probable that on some days the amount of water being used for irrigation amounted to double the average daily rate of application. It is conceivable that occasionally the application rate may have tripled. The tremendous difference in actual versus average use accounts for a large part of the apparent discrepancy between the theoretical average irrigation equipment requirements and the volume of such equipment that has been sold and installed. The significant fact is that carefully gathered statistical data show that in 4 years the total annual amount of water being used for irrigation has multiplied nearly eight times. The 1954 data used to make this comparison were taken from the 1955 report of the Delaware Water Resources Study Committee.

c. Sources of water supply used in irrigation. During 1957, when water used for irrigation on farms mounted to an all-time high of 1,554 million gallons, the University of Delaware made a study of the sources of water used for that purpose. Accurate data were received from operators on 95 of the 121 farms that practiced irrigation. These 95 farms used 79 percent of the total irrigation water.

Four sources of water for irrigation were considered. These were dug ponds, fed primarily by underground springs; impounded ponds and mill ponds; streams and lakes; and finally, driven or drilled wells. For the above 79 percent of the total irrigation water used on farms, the distribution of water sources was as follows:

Dug ponds	26.8%
Other ponds	6.7
Streams and lakes	48.0
Wells	18.5

Since all the water from wells and most of the water from dug ponds was of ground water origin, an approximate breakdown for distribution of irrigation water used can be developed to show the relative amounts derived from surface waters versus ground waters. That breakdown might be:

Surface Water	55%
Ground water	45

Accurate data for the remaining 21 percent of water used for irrigation are not available, but since this is a reasonably small percentage of the total, it is logical to assume the water sources for this amount followed the pattern set forth above.

17.07 WILL CHANGES IN AGRICULTURAL PROCEDURES TO MORE INTENSE FARMING ACT AS A FUTURE POPULATION GENERATOR?

It is logical to assume that the present trend will continue whereby the number of farms will decrease in the future, although the average size of farms will increase. Almost inevitably, the acreage in farmland today will also change. In New Castle County, almost all of the land now in farms can be expected to be used for homes, schools, industries, roads, parks, etc. Large areas of Kent County and of Sussex County farmland also will be converted to other uses. These changes, considered by themselves, would indicate a probable decrease in the agricultural population.

These same changes, however, will, among other things, be one of the principal reasons that agricultural land values will undoubtedly continue to rise. As the agricultural land becomes more valuable, two other changes must be expected. The first is that substantial areas of land now in trees may be cleared for crop production. This could conceivably reach such proportions that in the process of shifting land use about the net amount of land for crops may not be substantially reduced in spite of all of the new homes, schools, industries, roads, etc. Secondly, these increased land values will, at the same time, create an economic pressure that will force an intensification of farming practices. Certainly, if intensification occurs, a great increase can be expected in the acreage used for the production of vegetables. That increase will in turn develop a demand for additional labor, particularly during harvest seasons. That demand, on the other hand, will be tempered by the technological advances that will be made by the farm machinery manufacturers. It would thus appear, considering

the above factors alone, that we might expect little change, or even a slight decrease in permanent farm population, and from a small to a very substantial increase in seasonal farm population.

A third factor, however, must be considered. It has been pointed out that economic pressure will be one of the driving forces behind the probable shift toward intensification of farming. It must be expected, therefore, that gross income from agriculture will be greatly increased. Some of that increase will in turn be plowed back into the adjacent communities and towns. That will mean more business, and more business means more people. It thus becomes obvious, although the end result can not be predicted accurately, that agriculture can be expected to play a significant role in augmenting the future population of this State.

17.08 PROJECTED AGRICULTURAL PRACTICES AND THEIR RELATION TO AN INCREASED RATE OF WATER USE FOR IRRIGATION

The State Soil Conservation Commission recognizes that this section could be more vulnerable to question and attack than any other for which it has been assigned responsibility. For that reason, the approach being taken is to try to show what could happen within agriculture 50 and 100 years from now and to indicate the tremendous increase in demand for water which might result under certain foreseeable circumstances.

The long term trend in Delaware is definitely toward fewer cropland acres. The Agricultural Economics Department of the University of Delaware estimates that as much as 30 percent of the cropland used in 1900 had been converted to other uses by 1955. At that rate, by the year 2010, there could be only 300,000 acres of cropland in Delaware. To project even further to the year 2060, there might be only 100,000 crop acres in the State. Still using the same rate, within 25 years after 2060, there would be no cropland at all.

Considering population trends and future land requirements for towns, housing, roads, recreation areas, industrial sites, etc., it would, upon preliminary examination, seem to bear out some of the above figures. By the year 2060, for example, it is estimated that over 99 percent of New Castle County will be devoted to urban and industrial use. If this change in land use occurs, there would be less than 1,000 acres of land available in that County for cropland and private woodland combined.

Present day agricultural commodity surpluses and the resulting Federal programs to reduce crop production have had the effect of causing significant reductions in cropland use during the past years. Rising labor rates and increased machinery costs are also factors which must be taken into consideration. The increasing labor costs, which amounted to about 35 percent from 1948 to 1956, are putting great pressure on many farmers to reduce operations or to stop farming altogether. Paralleling that, the exceedingly high investment required to equip an average farm is most discouraging, particularly to the younger men who believe they would like to get into farming.

Individual farm income can be exceedingly unpredictable. Average hourly cash returns, considering all the labor put into farming, in many

cases, particularly in the industrial east, are often appreciably lower than those of other professions, especially when accurate accounting is done. In the face of this and the above factors, plus others, the existing trend toward less cropland in Delaware is completely understandable and entirely logical. Moreover, for a number of years to come, this same trend will undoubtedly continue.

The future, however, has new factors to offer. Beyond question, the most important of those is the probable shortage of land for crop production. The population growth in Delaware and in the entire United States has been phenomenal. The present (1958) population of Delaware is approximately 458,000. The projected population for the year 2060 is 3,352,100 people, almost four times as many as there are today--and they have got to be fed! Not only that, but their food must come from the lands that are left after these new people have built their houses and schools, their parks and churches, their roads, stores, and industrial sites where they will work.

Governor George D. Clyde of Utah made an address in December 1957 which was considered so important by Senator Arthur Watkins, also of Utah, that he requested and was granted permission to have the address printed in the Congressional Record. In that address, Governor Clyde quoted in turn from Mr. Donald A. Williams, Administrator of the Federal Soil Conservation Service: "In our time we shall see the rising population and the dwindling amounts of farmland meet. From that date on, you and your children can no longer be assured of the healthful, balanced diet to which we have become accustomed. When will this happen? The pessimistic crystal gazers say in another 10 years--the optimists claim not until the year 2000. But even the optimistic view is not pleasant to anticipate."

If Mr. Williams is correct, and he is certainly in a position to be considered an authority, we have little choice except to begin planning today to avoid or alleviate those possible shortages of food and fiber that could face this State and the country a hundred years hence.

Our first step is to inventory our most basic resource, the land. Fortunately, the U.S. Soil Conservation Service is well along with a farm-by-farm and field-by-field soil survey of the entire State. Fortunately too, over the years we have learned to correlate the ultimate potential use of our land to those soil surveys, and we have set up what are called land use capabilities.

From these the total acres of potential cropland can be accurately determined, without particular regard to present land use. Special limitations, such as need for drainage, or for erosion control, etc., are established and shown. Certain land within Delaware should not be cropped, but should be left or be developed as forest land or wildlife areas. These types of land are also determined.

Until the soil survey is finished exact figures will not be available. By projection methods, however, we can use the soils data already available to make reasonably accurate estimates. These are as follows:

	Total potential cropland -	Restricted to woodland	Restricted to wildlife area
New Castle	150,015 acres	3,579 acres	32,734 acres
Kent	326,600 "	4,500 "	49,526 "
Sussex	523,600 "	61,600 "	20,240 "

Based on these same soil surveys, which among other things show the present use of all of the lands, and again projecting the data on the same basis as above, the estimate for present land use is as follows:

	Cropland & grassland	Woodland	Wildlife area
New Castle	116,013	41,752	46,270
Kent	245,064	86,754	45,642
Sussex	336,345	238,520	18,345

An immediate reaction is to begin to compare the above two sets of figures. That would be a serious error. Consider New Castle County for example. What difference does it make that there are 150,000 acres of land which is suitable for perpetual cropping? Our best estimates are that by the year 2060 the homes and roads, the industries and parks, and all those other land uses, including State and Federal ownership, will have taken over all the land of the County, except perhaps a thousand acres. Even then we can not be sure that the thousand acres will be cropland; it could be private marshland or private forest preserve. For purposes of analysis, however, we can be reasonably safe in assuming that there may be no more than 1,000 acres of cropland left in that County by that date.

The situation in the other two counties will be quite different. In Kent County it is estimated that by 2060 a total of 144,000 acres will be required for non-cropland in the County. It is next necessary to make the assumption that the expansion of non-farm land use will, to a reasonable degree, take cropland, woodland, and wildlife areas in ratios somewhat comparable to the distribution of land use capabilities. On that basis, the maximum amount of land remaining which is suitable for cultivation might be 62 percent of 326,600 acres, or roughly 200,000 acres. Furthermore, it must be pointed out that this figure can be achieved only at the expense of clearing large areas of forests from lands which could be cultivated. In Sussex County the estimate for non-farm use by 2060 amounts to 120,000 acres, almost 20 percent of the County. Using the same assumption, about 80 percent of 523,600 acres, which is close to 420,000 acres, is the <u>maximum</u> amount of land suitable for permanent cropland. As with Kent, this can not be realized unless thousands of acres of existing woodlands are cleared for cultivation.

This report does not pretend to predict that such wholesale land clearing will be carried out by 2060. In the face of the combined

pressures of population, economics, and foreseeable land shortages, however, it is almost inevitable that drastic shifts in land use will come about. If our need for food becomes as great as some present-day authorities predict, it must be conceded that cropland will have very high priority. This report, therefore, assumes that it is possible that maximum use of cropland could occur.

That maximum use in the State, according to the above figures, could amount to a total of 621,000 acres. This compares with the estimated urban, industrial, highway, recreational, and other public uses which would amount to a total of 540,300 acres and leaves only 104,400 acres for all other uses, including remaining woodland, privately-owned marshes, and farm homesteads.

This unprecedented shift to cropland will hardly occur except under conditions of extreme need. Since we are assuming that the shift could occur, we are automatically assuming that such a need might develop. It follows that under such circumstances, maximum intensification of agricultural endeavors must be expected, that intensification will in turn undoubtedly place more accent on high return per acre of truck crops, and thi will increase the demand for irrigation water.

Considering irrigation, the present feeling of many technical agricultural people in this State is that supplemental water is an absolute requirement for maximum economic returns from certain crops. They also know that many other crops are substantially improved through the use of irrigation. Tests and studies made by these technicians attached to the University of Delaware are the basis for these conclusions.

Looking ahead to the future, with food needs increasing and with economic competition becoming even more intense, it must be calculated that irrigation of certain crops will become common practice. There seems little question, after the time comes when nearly every farm will have irrigation equipment, that the other crops will also be irrigated, because the initial cost and depreciation of that equipment will have been charged against the crops for which the irrigation equipment was purchased.

On that basis, the possibility exists that 100 years from now most of the Delaware cropland may be subject to supplemental irrigation, particularly in dry years such as 1957, provided there is enough water for the purpose. The calculation of the possible water requirements for such widespread irrigation is a matter of simple arithmetic.

Assuming that the maximum land use shift occurs, whereby 621,000 acres of cropland are being used by 2060, and assuming that 90 percent of this would, or at least should, be irrigated, by multiplication it is obvious that approximately 550,000 acres of cropland are involved. The average application of water at the present time is 7 or 8 inches per season Using the lower figure, the total application in a single year would be 3,850,000 acre-inches. Since one acre-inch equals 3,630 cubic feet, or 27,000 gallons, the total application, expressed in a different way, would amount to 103,950,000,000 gallons. It could be expected that

this might be applied over 60 irrigating days. In that event, 1,735,000,000 gallons per day is the amount of water under consideration.

That is a great deal of water, perhaps more than is available under any circumstances. There is no way to prove that the need will reach these extremely high figures, but it must be acknowledged that the possibility exists. The purpose of this report is to point out that possibility and to show that water, rather than land, might well be a prime limiting factor in the years to come. Many other factors, some of which probably are not known, or at least not recognized today, will shape the patterns of the future of many things, including agriculture, and within the latter, the scheme of ultimate land use. In submitting this part of the report we are among the first to recognize that it is largely conjecture. It is, however, backed up by several years of preliminary research. If by any chance it is even partially correct, the time is here to start action. That action is either to make plans to have available as much of the required water as possible, or to begin to make plans to get along without it.

SECTION XVIII
WATER POLLUTION COMMISSION

18-01. INTRODUCTION

Water is necessary for life - it is one of our most important natural resources. Sufficient quantities of water have been the key to the growth of many a nation, whereas insufficient water has been associated with a lack of growth. In the present age of increasing population and rapid industrial development this important natural resource must not only be conserved, but also its quality preserved.

In our way of life, conservation of water alone will not solve the present and future water problems. Conservation may insure sufficient quantity for the various human and animal needs; however, the use and degree of contamination will affect other needs downstream. Water, in its use, will receive natural and man-made contamination of considerable variation. It follows that requirements for quality control must be dependent upon the water usage involved.

Nature has provided us with the tremendous asset of self-purification.* To ignore this natural phenomenon would be wasteful. It becomes imperative, therefore, that a full understanding of this self-purification ability be considered so that pollution may be reduced to a level which does not exceed this natural purification capacity. Thus, it becomes fundamental that the degree of waste treatment necessary is dependent upon the best water usages and the ability of self-purification.

During the last decade, sportsmen, commercial fisheries, health, and similar organizations have become more and more active in combating pollution. Industrial committees, councils, and institutes have been established to study, disseminate information, develop research projects and operate pilot installations to evaluate specific types of wastes common to the particular industries. The cannery, dairy, paper and pulp, steel, and chemical industries are examples of this all-out effort to solve many of the existing problems.

Most states have more or less effective laws and regulations to enforce the abatement of pollution. Municipal ordinances are mostly confined to control the discharges and indicate necessary pretreatment. In addition to state and municipal laws, there are

*The ability of a body of water to consume natural and/or man-made contamination without impairing, within reason, best water usages.

authorities, commissions, and compacts which may control groups of municipalities, sections of one or several states, parts of river systems, or entire drainage areas.

a. Domestic waste. The handling of domestic waste has become less and less of a technical problem over the years. Procedures are reasonably well established whereby domestic waste can be handled or treated satisfactorily without excessive cost to the taxpayer. The flow patterns, waste characteristics, method of treatment and expected efficiency are reasonably well known. It should not be construed, however, that untreated domestic waste cannot be a serious problem.

b. Industrial waste. The technical difficulties and costs usually increase when industrial wastes are added to municipal systems or when an industrial waste is considered as a separate entity. There are numerous industrial wastes which can be readily treated when combined with domestic wastes. However, there are many industrial wastes to which no municipal system is available or which are not amenable to domestic or municipal-type treatment. Most of the difficulties encountered with the handling of industrial wastes can be attributed to unusual waste characteristics, changing of product and process (and the resulting waste) to meet changing needs, and the often excessive costs involved to provide satisfactory treatment facilities.

The effect of industrial waste discharges upon water supply and water use varies throughout the country and is dependent upon the distribution and type of industry. In the past, prior to the introduction of process water treatment, the location of many specific types of "wet" industries was determined by the character and quality of water available, as well as the availability of raw materials, labor, transportation, and markets.

As the river valleys grow with respect to population density and industrial development, each gallon of water available will experience additional reuse. The effluent quality will become of greater and greater significance. In many parts of the country reuse of the water is severalfold that of the total quantity available. It follows, therefore, that every effort should be made to make available as much water as possible, simply because invariably each successive use a gallon of water experiences, its subsequent treatment or purification to a desirable level becomes increasingly more costly. In a river valley such as the Delaware with its rapid development and numerous industries, the cost of additional treatment due to the unavailability of that "additional gallon of water" can conceivably cost its users many millions of dollars.

Although industry is generally widespread throughout the country, there are certain areas that are known for their concentration of industry. The waters in the Delaware Valley receive every conceivable type of waste discharge, even minute quantities of radioactive wastes; however, this latter type of discharge may become a problem in the not-too-distant future. The problems of radioactive

wastes are discussed in detail in a separate section. Waste discharges from industries, such as steel, oil refining, mining, wood pulp, paper, paperboard, coke, brewing, distillery, milk canning, textiles, tanning, meat packing, rayon, etc.--just to name a few--are all present in the Delaware Valley.

The State of Delaware has its share of industrial waste problems. We have various chemical industries, oil refining, steel, paper, textiles, tanning, nylon, meat packing, poultry, food processing, etc.

The problem of industrial wastes and their treatment is affected by the volume of dilution-water available and the permissible use of streams. In general, the more densely the area is populated, the greater the problem of industrial waste treatment and disposal. The waste volumes produced vary with the industry and within each industry. The extent of this variability is indicated by the estimated water consumption of a number of selected industries as shown in Table 1 (12).

Rudolfs (12) reports, "Aside from the variations in the types of industrial wastes and the uneven distribution of the industries, the magnitude of the problem is rarely realized. According to surveys made by the U. S. Public Health Service, the organic pollution contributed by the industries in the Ohio River Valley is about equal to the pollution contributed by the entire population. In industrial states, such as New Jersey, with some 2,000 industries producing liquid wastes, the waste volume is equal to that of the entire sewered population of the State, but the population equivalent* is greater. In Tennessee, industrial wastes are reported to have a pollutional effect on the streams equivalent to approximately 1.35 times that produced by the population discharging domestic sewage into the streams. Certain rivers or sections of rivers are subjected to volumes and concentrations of wastes far beyond the raw sewage population equivalents. The following two examples illustrate this point.

"The Androscoggin River in the region of Lewiston and Auburn, Maine, receives the municipal sewage from a summer population of 38,000, the sulfate waste liquor with a population equivalent of 1,500,000 and other wastes totaling 150,000 population equivalent. The lower Raritan River in New Jersey receives the treated sewage of about 175,000 people and the partially and untreated wastes, mostly chemical, from a number of industries totaling a population equivalent of about 825,000.

*Population equivalent is a means of comparing the strength of industrial waste loadings with domestic wastes. The amount of oxygen-demanding material and/or suspended solids present are used for comparative purposes.

TABLE 1

Industry	Number Establish-ments	Units	Gals per Unit	Mil. Gals (1947)
Steel (finished)	419	tons	65,000	4,020,721
Oil refining	437	bbl	770	1,453,675
Gasoline	-	bbl	357	791,325
Wood pulp:				
Sulfate		tons	64,000	342,829
Sulfite	226	tons	60,000	167,758
Soda		tons	85,000	41,784
Groundwood		tons	5,000	10,249
Paper	665	tons	39,000	415,226
Paperboard		tons	15,000	137,802
Coke	167	tons	3,600	284,493
Beer	440	bbl	470	41,373
Whiskey	226	gal	80	21,155
Milk, cream, butter	-	lb	0.11-0.25	12,286
Canning & preserving	2,265	cases	7.5-250	8,520/
Woolens & worsted fabrics	495	lb	70	3,252
Wool scouring	74	lb	1.26	2,648
Tanning	561	lb	8	1,910
Soap	249	lb	0.25	1,034
Meat packing, hogs	2,153	hogs	11	568
Cane sugar refining	25	tons	1,000	358
Rayon, all types	38	lb	0.16	119

"The average daily population equivalents of the more important oxygen-demanding wastes produced by groups of industries in the United States during 1949 are as estimated in Table 2 below (12)."

TABLE 2

Industry	Population Equivalent in Millions
Paper, pulp, board	43.6
Fermentation (alcohol, beer, wine, yeast antibiotics)	29.7
Packing and slaughterhouse	12.5
Textile, dyeing	9.9
Canning and freezing	9.3
Beet sugar	17.0
Petroleum refining	3.5
Miscellaneous (synthetic rubber, tannery, soap, fat processing)	4.7
	134.4

This listing does not include a large number of industries, such as pharmaceuticals, dyes, and power laundries. Further, more inorganic wastes, acids, alkalies, oils and brines are discharged in large quantities.

c. Philosophy of pollution abatement. It has been stated previously that treatment should be based on or be consistent with the water usages downstream. In the estuarine portion of the Delaware River Basin these needs are further complicated since both up and downstream users within the zone of influence can be affected materially due to the tidal movements. Generally, no two waste problems can be handled in the same manner. A blanket requirement as to method of treatment or degree or percentage removal is not consistent with the complexity of the problem.

Water uses may include municipal water supply, industrial process water, cooling water, water for navigation, recreation, fish and wildlife, shellfish, farming, and, strange as it may seem, as a recipient for treated waste. Constituents of wastes which may prove undesirable if discharged in sufficiently high concentration levels include essentially:

(1) Bacterial contamination, which could affect the potability and/or safety.

(2) Sediment discharge which will accumulate in the bottom of the streams and thereby affect biological life and fish propagation, in addition to being a deterrent to navigation.

(3) Putrefaction of inorganic sediment may blacken paint on boats and become offensive since, during decomposition of these solids, gas evolution, such as hydrogen sulfide, may take place.

(4) Certain chemical discharges may be toxic to fish and aquatic life.

(5) Excessive color discharge may prevent usage as an industrial water supply. Retardation of light penetration will also impair growth of plants and aquatic life.

(6) Wastes that are either too acid or too alkaline affect industrial and municipal water supply treatment. Corrosive action of these discharges is detrimental to shipping and other uses.

(7) Organic-type wastes, such as those discharged from fermentation industries, would, during stabilization, deplete the dissolved oxygen content in the water which, in turn, is harmful to aquatic life.

(8) Industrial wastes containing high concentrations of dissolved salts increase the hardness of the water, resulting in increased soap consumption and additional treatment for industrial water, specifically boiler waters.

(9) Excessive oil discharges will depreciate property, such as recreation facilities and boating, and will affect detrimentally fish and wildlife.

(10) Certain taste-producing substances, such as phenols, are most undesirable in domestic water supply and consumptive foods, such as fish and shellfish. These are just a few of the complications or variables to be considered in handling waste problems when multiple water usage is involved.

(11) Radioactive wastes: shellfish and barnacles accumulate heavy metals in their tissues.

The treatment of these various industrial wastes must be evaluated separately and specifically. Many of the larger companies investigate their local pollution control requirements, study conditions and flow of receiving waters at the locations under consideration, determine available diluting water, prepare and describe plans and specifications for treatment facilities to meet local requirements, and obtain formal approval of treatment works from the pollution control authorities.

This approach is considerably less difficult for new or expanding industries; however, for existing establishments the problem is

often more complex. Many industrial plants have been in operation for many years without adequate consideration of waste treatment disposal. The initial approach is usually to consider the possibility of modification of processes to change the character and reduce the quantity of waste.

A fundamental approach toward any industrial waste problem is to evaluate the possibility of reducing the waste by closer supervision of the processes or good housekeeping. An all-out effort to study the specific problem may lead to the segregation of wastes to simplify treatment procedures, to prevent undesirable interaction of undesirable wastes, to avoid difficulties, and provide information for the construction and operation of waste treatment plants.

Reuse and recovery of by-products is the first consideration of any industry faced with solving its waste problem. The possibility of the reuse of wastes for washing or cooling water purposes may result in a reduction of waste volume. This reduction of volume may not reduce the quantity of the pollutional material, but often a more concentrated waste can be treated at a lower construction and operating cost. By-product recovery is of interest to those industries where the products are valuable and salable; however, recovery of by-products from wastes is usually unprofitable. Making a profit from waste treatment is the exception rather than the rule, and it may prove costly and unwise to stress only achieving a profitable by-product in lieu of waste treatment. The revenue from by-product recovery may, however, pay, in part, for the cost of treatment for the remaining wastes. In this attempt to recover a by-product, new waste problems may arise which are equally undesirable or even more difficult to treat. A typical example of such a dilemma is often encountered from the evaporation of liquid waste material, in that the condensates formed are often highly pollutional.

Location and type of industry have a material effect upon treatment needs and the approach to the problem. Many of the known procedures which would normally be effective are not applicable to a seasonal industry which operates for only a few weeks or months of the year. For example, cannery wastes are usually highly concentrated and of short duration, and specific costly means of treatment are often necessary.

The philosophy of industrial waste treatment has changed considerably in the last two decades. In many of the industries, notably in the larger, waste treatment is considered an integral part of production. Waste treatment needs are evaluated by research, design, pilot plant, and full-scale operation. Competent disposal specialists are employed. Smaller companies usually employ outside consultants to help solve their problems. All other responsible, progressive, law-abiding companies are interested in abating pollution and avoiding misuse of watercourses. Their problem is to integrate waste treatment properly with production and to construct and maintain efficient treatment devices at the lowest possible cost.

In general, industrial waste treatment consists of one of the following principles:

1. Separation of solids from liquid.
2. Oxidation of organic and oxygen-demanding materials.
3. Neutralization.
4. Removal of toxic substances.
5. Disposal of residues.

To achieve these objectives, various procedures are used which employ physical, chemical, and biological techniques or combinations thereof. Solids are usually separated from the liquid by screening and sedimentation. This may also be done by centrifuges and flotation processes. In addition, the application of chemical coagulants and precipitants has been employed. Organic materials are usually stabilized by oxidation within biological treatment facilities. Aeration alone may prove helpful but is rarely sufficient or effective. Neutralization of acid wastes is usually done with lime, sodium hydroxide, sodium carbonate, or combinations of neutralization agents. Alkaline wastes are neutralized with sulfuric acid, carbon dioxide, sulfur dioxide, or flue gases, under certain conditions. The major problem, however, is sludge formation and disposal. Often the sludge problem is the major deterrent in neutralization procedures.

The removal of toxic substances is most difficult and requires specific methods of treatment. The procedures are usually chemical in nature; however, some of the toxicants are amenable to biological treatment.

The handling of residues from industrial wastes varies from slurries to precipitates and cakes, ranging in moisture content from 90% to 50%. Disposal procedures depend upon the character of the materials involved. If organic, they may be dried in the incinerator, used as fill, or placed on dumps. Each residue is a problem in itself. Waste treatment procedures must take into consideration proper and economical disposal of sludge. The effectiveness of handling the solid phase from many waste treatment processes is often the controlling influence as to whether waste treatment is successful or not.

The State of Delaware has no mining operations, except gravel pits, at the present time; consequently, pollution due to mining operations is nonexistent in the sense of discharging acid-type waste or mineral constituents from such operations. With respect to sediment load due to mining, numerous small gravel pits exist in the State of Delaware which discharge or have a potential discharge of sediment to various State waters. Of all the operations known to exist in the State, only one company has a potential problem. This organization has various settling ponds and essentially all the readily settleable material is removed. As is often the case, such gravel-washing operations will encounter a small portion of clay-like material which will remain in colloidal suspension. This material will reach State waters in the form of very fine turbidity and eventually may interact with other chemical constituents in the receiving body of water and settle to the bottom. Continued vigilance over such operations

must be made to keep this type of pollution at a minimum. The generally isolated location of the relatively small gravel-washing operations in Delaware does not create a serious problem.

Before proceeding with such items as the philosophy of stream pollution, domestic and industrial waste treatment, existing pollution, abatement facilities, laws, rules and regulations, accomplishments, etc., in Delaware, it would be well to state as concisely as possible what is the problem with respect to pollution of waters within the jurisdiction of the State of Delaware. It is conceivable that since water uses in the State of Delaware are quite similar to those of the entire Delaware River Basin; in some respects the problems are congruent.

Pollution affects each and every water use, and consequently, its influence is fundamental to the future of each interest. Present water quality varies from polluted areas to conditions where little or no pollution exists. Obviously, we cannot survive or remain prosperous if we permit detrimental pollution to continue. Neither can we prosper if we demand the complete removal, without exception, of all contamination reaching State waters. In order to achieve a static state of no contamination of State waters, man could not or would not be permitted to use such waters. It is generally accepted by the majority that some contamination is unavoidable and that waste treatment is needed to reduce, not completely eliminate, such contamination. It follows that each user may be required, of necessity, where more than one user is involved, to accept water of lesser quality than he would consider the optimum for his specific interest. Similarly, a polluter is obligated to treat his waste even though he feels he is entitled to the use of the stream as a recipient of his discharges. It is inevitable that a compromise or, more appropriately stated, an equitable solution be sought.

A limit to the degree of contamination, which can be accepted within reason, must be prescribed within the realm of best water usage. Domestic raw water supply requirements can vary from demanding no contamination (no use of upstream water) to the contamination of such water as long as the ability to supply a safe and palatable water is not endangered or impaired. In a multipurpose stream, complete treatment for domestic water supply is unavoidable. Pursuing this line of reasoning, the various water users affecting the water quality of a stream must pattern the treatment of their discharges so that the primary use is not endangered. What degree of treatment should be required of the upstream water users in this instance?

We fully realize that a body of water is capable of self-purification, provided this ability is not abused. We are also aware of the fact that the extent of self-purification is dependent upon specific characteristics inherent in each body of water and these characteristics may differ markedly from place to place. Further, to evaluate this ability to recover, such factors as time, temperature, distance, weather conditions, volume of flow, reaeration, dispersion, etc., must be considered. In estuaries, additional factors, such as tidal movement, height of tide, and flushing time, must also be

considered. Two similar discharges located 10 and 20 miles upstream from a domestic water intake would not affect the quality of this supply equally. Similarly, different types of wastes will experience self-purification to varying degrees. Should we require the maximum degree of treatment known to exist for all discharges located upstream regardless of distance or self-purification capacity available?

Let us examine this request more critically. There are various degrees of treatment presently known for domestic and industrial waste. Treatment procedures employed may be subdivided, in a general manner, into primary and secondary or complete treatment. Primary treatment for domestic wastes normally means removal of settleable and floating solids followed by some means of disinfection. Primary treatment for industrial waste may mean pretreatment, good housekeeping, removal of settleable solids, neutralization, or reduction of toxic and taste-producing constituents to a low level. Secondary or complete treatment for a domestic-type waste means further stabilization of the resulting effluent after primary treatment by means of biological oxidation or stabilization followed by disinfection. Complete treatment for an industrial type waste is far more complex since it means not only stabilization of its organic constituents in its effluent after primary handling, but also the removal of a majority of its dissolved inorganic compounds.

Adding secondary treatment to domestic waste may increase construction cost as much as 40%. To treat industrial wastes completely involves a considerably greater percentage. The industrial picture is further complicated by the fact that procedures may not be available to treat completely their discharges. If an industry is fortunate to be near enough, barging to the ocean may be the solution. Aside from the costs of barging, the selection of ocean disposal areas can become quite controversial.

There is little doubt that economics are a major factor in all waste treatment. Whether it be a municipality or an individual industry, each will search for the most economical means of handling its problem, taking into consideration the self-purification ability of the receiving body of water between the discharge and the other water users. Excessive waste treatment requirements may prevent industrial growth or make its position untenable.

The problem of deciding whether primary or secondary treatment procedures should be constructed at the present time involves an additional complication. We are obligated to look to the future, and as such we must realize that both population density and industrial development will increase. The decision must be made whether the anticipated increase in population and/or industrial development will warrant a directive for the immediate construction of secondary or complete treatment facilities in all instances.

Domestic waste treatment facilities are designed, as a rule, for anticipated expansion 25 years hence. This period is selected because the designing engineers feel that it is economical design period since it is the average life span of such structures. With industry, the basis for design is far more critical. Sudden changes in operation, new processes,

and increased production tend to make it most uneconomical and impractical to design treatment which would be required 25 or more years hence. Further, if population density or industrial development should not take place in a specific area as predicted, additional construction requirements and costs of operation would indeed be an inequitable burden upon those paying the bill. It is, therefore, more appropriate to require that initial treatment take into full consideration the stream's natural purification capacity, with the proviso that space be provided to install additional treatment if and when needed.

The question of equity becomes even more difficult as we delve into other water uses. For example, decisions with respect to domestic water supply are less complicated simply because the intake is at a specific location and the sources of pollution are at designated distances from the intake. When we consider such usages as recreation, parks, boating, sport fishing, fish, wildlife, and shellfish basic productivity, the principle of employing or utilizing the self-purification capacity of the stream becomes more complex. These interests or needs for recreational facilities are dependent upon the population concentration. Thus, the facilities are progressively more valuable the closer they are located to the population centers. As we move closer to the sources of waste discharge, however well treated, we are progressively decreasing the available self-purification capacity of the particular body of water in question. Parks and playgrounds have greater flexibility of location and can, under certain circumstances, be so placed as not to conflict with the full use of a stream's self-purification action. Unfortunately, natural oyster beds and marsh areas do not have flexibility with respect to location. To protect these latter usages, the zone of influence from municipal and industrial waste discharges must be carefully ascertained. A buffer zone between these latter usages and sources of waste discharge becomes a basic necessity. To avoid complete destruction of such usages as natural shellfish and marsh areas, limiting domestic, recreational, and industrial development in certain localities becomes unavoidable.

In an effort to be realistic, one must conclude that it is inevitable that we will have increases of population and to support this increase in population we must have industrial development. In existing areas of moderate to heavy population and industry density it is only reasonable or equitable to conclude that the self-purification action of a stream must be considered as an integral part of pollution abatement. Further, to provide for the inevitable population growth and industrial development, it appears both reasonable and equitable to assume that areas involving comparatively minor facilities or assets for fishing, recreation, boating, parks, etc., will give way to various degrees of urbanization and industrialization. All major recreational usages, however, must be fully protected. The need for such assets is also an integral part of our way of life. It is conceivable that we will eventually reach a point of saturation whereby further advancement in growth and development must be limited or we will destroy what we strive to preserve at the present time. When that time comes, other undeveloped areas of this nation will experience rapid growth and development. We must not be placed in a position whereby we are saturated with population and industry without the recreational facilities needed for full enjoyment of life itself.

18-02. POLLUTION ABATEMENT LAWS

a. State Board of Health. Prior to the passage of the Water Pollution Control Act of 1949 (1) waste control and abatement was carried out under several laws within the jurisdiction of the State Board of Health and the Fish and Game Commission. These laws were originally listed in the Code of 1915. The State Board of Health had the specific power and duty (13) to:

"Provide for the sanitary protection of all water supplies which are furnished to and used by the public; and

"Provide for the proper collection, storage, and disposal of sewage, household wastes, and garbage by public authorities and individuals."

Further, the Board of Health laws (14) specifically set forth the protection of streams against pollution, especially those waters used for supplying drinking water for any borough, town, or city within the State.

"No person shall cast, put, place, discharge in, or permit or suffer to be cast, put, placed, discharged in, or to escape into any running stream of water within the limits of this State, from which stream the inhabitants of any borough, town or city within this State are supplied wholly or in part with water for and as drink or beverage, any dye-stuffs, drugs, chemicals or other substances or matter of any kind whatsoever, whereby, and by means whereof, the water so supplied as and for a drink or beverage is made and becomes noxious to the health or disagreeable to the senses of smell or taste."

The treatment of refuse from fowl and poultry dressing is also controlled by law under the jurisdiction of the Board of Health (15).

The State Board of Health, by rules and regulations, prescribes "the methods and means of treating any blood, garbage, carrion, offal, filth or other refuse from the dressing of fowl and poultry so as to remove the noisome or obnoxious nature thereof."

The State Board of Health laws specifically prevent municipal discharges from reaching state waters without proper treatment and also include industrial wastes having access to domestic sewers. The laws completely protect all public water supplies; however, industrial wastes entering state waters directly do not appear to be specifically controlled, except poultry and/or slaughterhouse wastes.

b. Game and Fish Commission. The Game and Fish Commission has two laws with respect to contamination or pollution reaching the State waters. The first law (16) applies specifically to discharges entering the Delaware River or Bay as follows:

"No person shall wilfully put or place in the waters of the Delaware River or Bay any explosive substance whatever, or any drug or

poisoned bait for the purpose of catching and taking, killing or injuring the fish, or allow any dye stuff, coal or gas tar, sawdust, tan bark, coculus indicus (otherwise known as fish berries), lime, refuse from gas houses, oil tanks or vessels, or any other deleterious, destructive or poisonous substance to be turned into or allowed to run into any of the waters aforesaid, in quantities sufficient to destroy or impair fish life or disturb the habits of fish inhabiting the same."

This has been elaborated to include other streams in the State (17) as follows:

"None of the waters of this State shall be polluted in any way by permitting the entry therein of any waste or deleterious substance in sufficient quantities to injure or destroy any fish or render such fish unfit for food."

It is possible that the Game and Fish regulations have not been fully applied in the past due to administrative complications. Further, where multiple discharges of many different types of wastes exist, such as in the Delaware River upstream from the State line, it would be most difficult to establish which source is accountable or responsible for damage to fish life. One of the primary reasons for the passage of the Delaware Pollution Control Act of 1949, discussed below, was to create a specific group which could handle the industrial problems and the other waste problems in view of the needed complex evaluations or studies. The Water Pollution Control Act, however, states that nothing in its make-up should be construed to limit or modify in any manner the powers and duties of the State Board of Health or the Game and Fish Commission under existing laws.

c. Interstate Commission on the Delaware River Basin. One of the initial steps to conserve and to safeguard water resources in the Delaware River Basin was instigated and set forth in a reciprocal agreement between the four states involved; namely, the Commonwealth of Pennsylvania, State of New York, the State of New Jersey, and the State of Delaware. This reciprocal agreement (18) under the administration of Incodel, and commonly referred to as the "Incodel Program", was approved by New York in May 31, 1939; New Jersey July 1, 1939; Delaware May 8, 1941; and Pennsylvania April 19, 1945. The reciprocal agreement became effective July 10, 1945, with respect to Delaware when, according to conditions of the agreement, all of the other States had approved the agreement. This Incodel Chapter sets up four zones along the Delaware River including minimum requirements in each of the zones. Zone IV is that part of the Delaware River extending from the Pennsylvania, New Jersey, and Delaware boundary line to the Atlantic Ocean.

The principal uses of the waters of the Delaware River in Zone IV are "expected to be for navigation, industrial water supplies, commercial and pleasure fishing, shellfish culture, recreation, and other purposes."

In order to attain conditions of cleanliness and sanitation of the waters of the Delaware River which will be consistent with the

appropriate existing and future quality and uses of such waters, the following minimum requirements shall apply to Zone IV. It is the purpose and intent of such requirements to apply to artificial (not natural) causes of pollution.

Zone IV

(1.) Such effluent shall be free of noticeable floating solids, oil or grease and substantially free of both settleable solids and sleek.

(2.) Such effluent shall be sufficiently free of turbidity that it will not cause substantial turbidity in the waters of the Delaware River after dispersion in the water of the river.

(3.) Such effluent shall show a reduction of at least 55% of the total suspended solids and shall be subject to such further treatment as may be needed to prevent a nuisance.

(4.) Such effluent, if it is discharged within prejudicial influence of a public water works intake, or of recreational areas, or of shellfish grounds, shall at all times be effectively treated with a germicide, except that in the case of recreational area influence, such treatment need not be provided during the period from October 15th to May 15th of each year.

(5.) Such effluent shall be sufficiently free of acids, alkalis, and other toxic or deleterious substances that it will not create a menace to the public health through the use of the water of the Delaware River for public water supplies, or render such waters unfit for commercial fishing, shellfish culture, recreational, industrial or other purposes.

(6.) Such effluent shall be practically free of substances capable of producing offensive tastes or odors in public water supplies derived from the Delaware River.

d. Water Pollution Commission. The Delaware Water Pollution Control Act as it now exists was passed in 1949. This Act created a Commission, consisting of:

The President of the Game and Fish Commission, the President of the Delaware Commission of Shell Fisheries, the Chief Engineer of the Wilmington Water Department, the New Castle County Engineer, the Chief Engineer of the State Highway Department, the Executive Secretary of the State Board of Health, the Director of Division of Sanitation, and one representative of industry from each of the three counties of the State, appointed by the Governor, by and with the consent of the Senate.

The policy under which the Commission operates is expressed as follows:

"It is declared to be the public policy of the State to maintain within its jurisdiction, a reasonable quality of water consistent

with public health and public enjoyment thereof, the propagation and protection of fish and wildlife, including birds, mammals, and other terrestrial and aquatic life, and the industrial development of the State."

The purpose of the Pollution Control Act is as follows:

"It is the purpose of this chapter to safeguard the quality of State waters against pollution by (1) preventing new pollution in such waters, and (2) controlling any existing pollution."

The State Board of Health is designated as administrative agent for the Commission on Water Pollution. It is also directed to make such inspection or conduct such investigations, and do such other acts as may be necessary to carry out the productions of this chapter. The administrative agent shall have all the powers conferred by law upon the Commission, except that of enacting the orders, rules and regulations, provided in this chapter, subject, however, to the general direction of the Commission and the rules and regulations which it may adopt. The Water Pollution Commission is responsible for coordination and administration of Interstate and Federal pollution control progress with respect to Delaware.

A few of the duties and powers of the Commission, set forth in the law, which directs its operational policy follows:

(1.) "To study and investigate all problems connected with the pollution of the waters of the State and its control and to make reports and recommendations thereon.

(2.) "To conduct scientific experiments, investigations, and research to discover economical and practicable methods for the elimination, disposal, or treatment of sewage, industrial wastes, and other wastes to control pollution of the waters of the State. To this end the Commission may cooperate with any public or private agency in the conduct of such experiments, investigations, and research and may receive on behalf of the State any moneys which any such agency may contribute as its share of the cost under such cooperative arrangements.

(3.) "To issue general orders, adopt rules and regulations applicable throughout the State for the installation, use, and operation of systems, methods, and means for controlling the pollution of the waters of the State by sewage, industrial wastes, refuse, and other wastes....

(4.) "To make investigations and inspections to insure compliance with any general or special orders, rules and regulations which the Commission may issue. In the exercise of this power the Commission may require the submission and approval of plans for the installation of systems and devices for handling, treating, or disposing of sewage, industrial, and other wastes."

e. Control Policy. In accordance with these duties and powers the Commission adopted on February 7, 1952, the Delaware Water Pollution Control Policy, revised July 19, 1957. This policy specifically states:

"With regard to new pollution, General Orders Nos. 1 and 2, adopted by the Commission on March 30, 1951, are regarded as sufficient to accomplish this. By the requirements of submitting plans or reports, new pollution will be effectively controlled. These same orders will be effective in requiring specific degrees of treatment where projects are contemplated for controlling existing pollution.

"The program for controlling existing pollution operates in the following manner: The waters of the State are studied and surveyed by drainage basin areas. These investigations show the current stream conditions, the wastes being discharged, the effects of these waters, and the best uses of the streams in the various areas.

"Based on the best uses in the various stretches of the streams, the Commission agrees concerning the degree of treatment that is needed for each waste being discharged. When this has been done, the person responsible for the pollution is advised concerning the Commission's findings. Such advise is by letter, transmitting a copy of the appropriate basin report. In the letter, pertinent sections of the report are indicated and the extent to which his waste discharges need to be improved is stated, either in terms of maximum acceptable amounts of important constituents, percentage reduction of significant pollutants, or the type or degree of treatment considered to be necessary. The letter also requests that the person causing the pollution advise the Commission, in writing, concerning the steps which are being taken or will be taken to reduce the discharge of polluting substances by the required amount. The particular methods by which required correction is accomplished is the responsibility of the person causing the pollution.

"If the offender shows good faith in correcting the problem, no further action is taken. However, if he does not evidence good faith, and fails to take specific action toward accomplishing correction, the Commission issues a special order requiring that the necessary improvement be accomplished within a specified period of time.

"Commission requirements will remain in effect within a specific drainage basin area as long as the demand for the stream's assimilative capacity is not endangered. Should domestic, institutional, and/or industrial waste requirements approach this capacity, the Commission will review its requirements with the understanding that additional treatment may be required of each of the interests discharging wastes into the drainage basin under consideration. Once maximum treatment, employing reasonable and accepted procedures, is provided by all, the stream's assimilative capacity may become a limiting factor to further domestic, institutional, and/or industrial growth within a specific drainage basin.

"The provisions in the Incodel law, as they apply to Delaware waters, are upheld by the Commission and used as minimum requirements where applicable. In other cases, additional measures are required to protect the best water usage."

18-03. POLLUTION ABATEMENT PROGRAM

The staff was hired and a laboratory established in 1950. The Water Pollution Control Program has been carried out within the scope of the Water Pollution Control Policy discussed above.

Essentially, the program is divided into several categories, namely:

1. Survey of existing pollutional problems.

2. Preparation of comprehensive survey reports, with recommendations for needs in each basin.

3. Review of plans for construction and completion thereof.

4. "Follow-up", involving compliance with recommendations and measurement of efficiency of plant operation.

5. Publicity (2) which includes a general report to the public, talks before various civic groups, radio talks, individual speeches and technical papers on investigative work.

a. Basin survey status. The field investigation status is set forth in Table I (19). Herein are itemized the various drainage basin areas, including the length of the stream in miles, drainage areas in square miles, and the percentage of the total drainage area each basin represents. In addition, the current survey status is set forth.

Completed basins that have been both surveyed and reported on include the Indian River (3), Buntings Branch (4), Broadkill River (5), Mispillion River (6), Red Clay Creek (7), Brandywine Creek (8), and the Nanticoke River (9). A considerable amount of data has been accumulated on the White Clay Creek, but no report has been prepared. A much greater effort is being expended toward the investigation of the Delaware River proper. Added emphasis is needed here, due to the complexity of the problem, in establishing pollutional abatement needs. Two preliminary Delaware River investigations have been made and reported on: the Accumulation of Iron within the Delaware River (10) made in 1952, and in 1956 a Report on Sanitary Water Quality (11). Further work is being conducted on the river at the present time, to compile and report data which have been collected in a cooperative study with Incodel and the Academy of Natural Sciences, with respect to the purification capacity of the estuary portion of the Delaware River. Details of the Delaware River studies are discussed and evaluated below.

TABLE I (19)

SURVEY STATUS OF STREAMS WITHIN DELAWARE

Basin	Total Length of Streams, miles	Drainage Area sq. mi.	Percent of total drainage Area %	Survey status*
Nanticoke River	125.4	270	17.0	A
Broad Creek[1]	62.9	125	7.9	A
Indian River	165.9	310	19.5	A
Buntings Branch	7.5	14	0.9	A
Broadkill River	60.3	110	6.9	A
Mispillion River	79.3	125	7.9	A
Murderkill River	63.3	107	6.8	C
St. Jones River	73.6	94	5.9	B
Little River	24.4	27	1.7	D
Dona River	19.5	22	1.4	D
Leipsic River	44.7	68	4.3	D
Smyrna River	63.5	68	4.3	C
Blackbird Creek	29.0	31	2.0	D
Appoquinimink Creek	44.4	47	3.0	B
Christina River	63.1	66	4.2	B
Red Clay Creek[2]	23.6	23	1.4	A
White Clay Creek[3]	53.8	45	2.8	A**
Brandywine Creek[3]	36.4	33	2.1	A
Delaware River	33.69	381***	-	B

*A--Completed
B--Partially Complete
C--Contemplated in near future
D--Survey under consideration

[1]Tributary to Nanticoke River
[2]Tributary to White Clay Creek
[3]Tributary to Christina River
**Report not compiled

***Drainage area is the sum of the 8 drainage basins in New Castle County tributary to the Delaware River.

 (Revised March 1960)

A closer review of progress in the State of Delaware with respect to survey work is set forth in Table II (19). It may be noted that completed basins constitute 49.3%, and partially completed 12% (includes Delaware River) of the total drainage area in the State of Delaware. Basins to be completed in the near future and under survey total 3%, and areas under consideration constitute 12%. This latter 12% consists of areas that will be surveyed in the future and will constitute the last remaining portions of the State that need such survey work. Approximately 24% of the State consists of areas requiring no investigation since either pollution is quite nominal or not evident within the receiving streams. In summation, therefore, approximately 85% of the State's surveyable basin areas have either been completed, or are partially complete at the present time. In essence, the initial investigation or evaluation of pollutional problems in the State of Delaware, for all practical considerations, have been completed in the first eight years of the Commission's existence.

b. Waste treatment facilities and operation. The State of Delaware pollution inventory as of 1957 is recorded in the Water Pollution Commission 8th Annual Report (19).

A major factor in the success of any pollution abatement program is the efficiency of waste treatment operation. Adequate treatment facilities can understandably become ineffective in curbing stream pollution if the plant does not have proper operational control. The number of installations, both industrial and domestic, have increased materially, and this follow-up phase has become a major part of the Water Pollution Program. In addition, instruction and assistance is provided wherever needed to effect proper operation.

(1.) Waste treatment inventory. The municipal waste collection and treatment picture in the State of Delaware is reasonably good. Of the total 51 communities listed in Table II (19), 40 have treatment provisions. In addition, eight municipalities are actively engaged in providing waste treatment. At the present time there are only three communities which may need immediate attention. One of these communities is Greenwood which is under direction to proceed with the planning and construction of treatment facilities. The other two communities are in basins which have not been surveyed, and these municipalities will be taken into consideration in the near future.

The institutions present an excellent record. Only one institution, Governor Bacon Health Center, does not have treatment. This need is being rapidly corrected with treatment provided in a joint operation with Delaware City. Detailed plans have been completed and construction should commence shortly.

The industrial picture also shows good progress. Delaware has a great number of industries, both small and large, for its size. Of this total, 380 or 56% are considered wet industries having a liquid process waste. Of these wet industries, 280 enter a municipal system. Treatment is provided for 332 wet industries, or 87.5% of the total.

TABLE II (19)

SUMMARY OF WASTE TREATMENT FACILITIES [a] IN DELAWARE
JUNE 1958

County	Municipalities		Institutions	
	Total Number	Treatment Provided	Total Number	Treatment Provided
New Castle	9	8	8	7 [c]
Kent	21	17	2	2
Sussex	21	15	2	2
Total	51	40 [b]	12	11

County	Industries			
	Total Number	Dry Operations [d]	Wet Operation	Treatment Provided
New Castle	351	88	263	255
Kent	146	110	36	30
Sussex	180	99	81	47
Total	677	297	380 [e]	332 [f]

(a) Includes all types, and degree of efficiency. Active follow-up file includes 20 municipalities, 4 institutions and 100 industries.
(b) Not included in number are 8 communities actively engaged in providing waste treatment needs.
(c) The one institution without treatment has provided detailed drawings for review to be followed by construction.
(d) No process water. Domestic waste either in municipal system or septic tank.
(e) 250 of this total enter municipal systems with treatment and 30 without.
(f) Of this balance, namely, 48 locations without treatment, 30 of these now enter municipal systems without treatment who are under active planning toward construction.

Of the remaining 12.5% which constitutes a total of 48 industries, 30 now enter municipal systems, and are not considered as having treatment since the municipalities have no treatment facilities. However, these 30 industries are in municipal systems actively planning construction.

The waste treatment picture in Delaware looks promising; however, it must be remembered that, although treatment is provided in many instances, constant diligence in efficiency of operation must be maintained. In addition, upon investigation, some of the existing facilities may need additions or modifications. A more realistic picture is set forth in our follow-up file, which is considered the active phase of treatment status in Delaware. Periodic checking of 20 municipalities, 4 institutions, and 100 industries is being continued.

(2) Pollution reduction inventory. The estimated pollutional loading in the State of Delaware as of June 1958 is presented in Table III (19).

Estimated reduction of pollution, both domestic and industrial, approximates 73%. This overall reduction is a complete evaluation. It is highly probable that, except for some localized problems, the ability of self-purification of the waters within the jurisdiction of the State of Delaware is not being exceeded by this loading.

TABLE III
ESTIMATED POLLUTION LOADINGS IN DELAWARE
JUNE 1958

Type of Waste	Potential P.E.***	Effluent Loading P.E.***
Domestic*	425,000	160,000
Cannery	70,000	35,000
Chemicals and Allied Products	155,000	82,000
Poultry and Meat	360,000	18,500
Paper and Allied Products	80,000**	11,500
Petroleum and Coal Products	760,000	60,000
Miscellaneous	50,000	35,000
Industries to Wilmington and New Castle County System	550,000	215,000
TOTAL	2,381,500	617,000

* Excludes industrial additions from municipal systems which have both industrial and domestic wastes.

** 68,500 of this total enters the Wilmington waste treatment system and total reduced by this amount accordingly since load included in industry load to Wilmington.

*** Population Equivalent.

18-04. INVENTORY OF PRESENT INDUSTRY

A 100% inventory was made of all industry in Delaware as of 1957. The type industry and its water source is presented in Tables I-1, I-2, and I-3. These tables show type of industry; those receiving municipal water; and those which use a private water source. Industries are segregated in such a manner as to present major groups having similiar pollutional problems. The miscellaneous groups include a multitude of very small industries which utilize, in essence, very small amounts of water or the large steam generation plants with no waste handling problems. These industrial types are classed as Cannery & Dairy; Chemical & Allied; Poultry, Meat & Fish; Paper & Allied; Petroleum & Petroleum Products; Metals; and Miscellaneous.

Distribution of industry in Delaware by type and/or water supply can be evaluated from Tables I-1, I-2, and I-3. Of the total number of industries receiving water from municipal water sources (Table I-1) approximately 50% are small water users. In excess of 50% of these small industries are located in New Castle County. Fifty of the 170 industries in Kent and Sussex Counties are significant water users. It is readily apparent that the metals, petroleum and petroleum products, paper and allied industries which receive water from municipal installations are in New Castle County. In contrast, the poultry, meat and fish-type industries are in greater number in the lower two counties. Cannery and dairy-type industries are equally distributed between New Castle and the lower two counties. The chemical and allied industries are predominantly in New Castle County; however, Kent and Sussex do have 20 such industries as compared to 72 in New Castle County. Industries with private water sources (Table I-2) show essentially a similar picture with respect to metals, petroleum and petroleum products, paper and allied industries, in that very few such industries are located in Kent and Sussex Counties. When we compare the poultry, meat and fish-type industries, we note that these are predominantly located in the lower two counties, with New Castle having only 8 such industries, Kent 15, and Sussex 27. Again, private sources show chemical and allied industries to be located primarily in New Castle County. Cannery and dairy are reasonably well distributed, with Kent County having the greatest number.

TABLE I-1.--INDUSTRY - 1957 INVENTORY

TYPE AND MUNICIPAL WATER SOURCE

Industry Type	New Castle Ground	New Castle Surface	Kent Ground	Kent Surface	Sussex Ground	Sussex Surface	Total
Cannery & Dairy	-	10	7	-	5	-	22
Chemical & Allied	10[A]	62	10	-	10	-	92
Poultry, Meat & Fish	2	7	4	-	11	-	24
Paper & Allied	3	8	1	-	1	-	13
Petroleum & Petroleum Products	1	5	1	-	-	-	7
Metals	9[A]	41	3	-	3	-	56
Miscellaneous	21[A]	109	35	-	69	-	234

A - One of this total has both ground and surface water.

TABLE I-2.--INDUSTRY - 1957 INVENTORY
TYPE AND PRIVATE WATER SOURCE

Industry Type	COUNTY						Total
	New Castle		Kent		Sussex		
	Ground	Surface	Ground	Surface	Ground	Surface	
Cannery & Dairy	15	1	27 b-5	-	17 a,b	1	61
Chemical & Allied	11 C-2	8 a,d,C-5	4 a	2	2 a	1	28
Poultry, Meat & Fish	6 b	2 c	14 a,b	1	26	1 b	50
Paper & Allied	6 b,a-3	8 c,b	-	-	-	-	14
Petroleum & Petroleum Products	2 c	2 a,b	1	-	-	-	5
Metals	4 b,e	3 d,C-2	2	-	1	-	10
Miscellaneous	19 b,C-2	2 c	29 b,a-2	5	34	4 b,a-3	93

Footnote Legend - Example a-2, means 2 industries in a category.
(a) One industry has surface water source.
(b) One industry has municipal ground water source.
(c) One industry has municipal surface water source.
(d) One industry has private ground and municipal surface water sources.
(e) One industry has municipal ground and municipal surface water sources.

TABLE I-3.--INDUSTRY - 1957 INVENTORY
CLASSIFICATION, TYPE

Industry Type	COUNTY			
	New Castle	Kent	Sussex	Total
Cannery & Dairy	27	30	21	78
Chemical & Allied	85	15	12	112
Poultry, Meat & Fish	13	19	38	70
Paper & Allied	20	0	1	21
Petroleum & Petroleum Products	7	2	0	9
Metals	50	4	4	58
Miscellaneous	144	72	103	319

18-05. NON-CONSUMPTIVE USES OF WATER BY COMMERCIAL AND INDUSTRIAL USES

A summary of water use in the State of Delaware, as of 1957, is presented in five separate tables. Each of these tables is divided into three sections; namely, Maximum use, Average, and 30-day Maximum. These presentations were prepared in this manner in order to fulfill the needs associated with the variability of water demand. The Maximum use data provide an indication of the instantaneous demand and show the comparative magnitude for peak period design. The Average tabulations indicate total use or storage requirements over an extended period of time. The 30-day Maximum, however, is the most valid presentation of present needs and the basis for future projections. The latter essentially pertains to periods of dry weather conditions when water is in greatest demand.

Industrial water inventory for the State of Delaware is presented in Table 1. These cover all industrual water uses as of 1957, ground and surface sources, whether they are derived from municipal systems or from private utilities.

The municipal water inventory is presented in Table 2. These presentations include all waters supplied by municipal systems, whether they are delivered to industry or to the public. In addition, Table 2 presents an estimate of rural water usage assuming 50 gal./capita/day.

Total ground-water inventory is presented in Table 3. This tabulation shows all waters taken from the ground whether they are industrial or public, consisting of summation of values presented in Tables 1 and 2. Miscellaneous uses are included in Table 3, consisting of ground-water sources at institutions and military installations not supplied by either municipal or industrial water sources. This municipal ground-water inventory includes rural wells which were recorded in Table 2.

Surface water inventory is presented in Table 4. This includes all surface waters, both industrial and public; however, irrigation uses are added. The irrigation tabulation is a composite of both ground and surface sources. No separation was possible since the data were reported as inches applied per acre of land.

The total summary of all water use in the State of Delaware is presented in Table 5 and is self-explanatory. These summary water uses as recorded constitute, for all practical considerations, a 100% inventory of industrial, domestic, institutional, military, and irrigation use.

The portions of each of these five tables denoting Maximum use provide an indication of the instantaneous demand as referred to above. For expedience, however, collection of complete Maximum data, specifically with respect to surface water, was not made and therefore these tabulations are conservative. The Maximum, as expressed under public surface and ground-water installations, are the same as the 30-day Maximum. The instantaneous Maximum would be greater. In addition, the 30-day Maximum was recorded as the instantaneous Maximum for most of the steam generation uses.

TABLE 1 -- INDUSTRIAL WATER INVENTORY - 1957
STATE OF DELAWARE

County	No. Ind.	Ground Water, gpm Public	Ground Water, gpm Private	Surface Water, gpm Public	Surface Water, gpm Private
			MAXIMUM		
New Castle	351	530	16,875	18,800	648,156
Kent	146	1,422	18,243	none	6,570
Sussex	180	1,798	22,981	none	161,630
TOTAL	677	3,750	58,099	18,800	816,356
			AVERAGE		
New Castle	351	467	8,450	13,030	423,364
Kent	146	988	10,538	none	4,250
Sussex	180	904	16,198	none	95,315
TOTAL	677	2,359	35,186	13,030	522,929
			30-DAY MAXIMUM		
New Castle	351	530	12,597	18,800	503,281
Kent	146	1,422	14,702	none	5,070
Sussex	180	1,798	19,172	none	125,415
TOTAL	677	3,750	46,471	18,800	633,766

TABLE 2 -- MUNICIPAL WATER INVENTORY - 1957
STATE OF DELAWARE

County	Ground Water, gpm Rural*	Ground Water, gpm Domestic	Ground Water, gpm Industrial	Surface Water, gpm Domestic	Surface Water, gpm Industrial
			MAXIMUM		
New Castle	540	5,230	530	15,800	18,800
Kent	1,370	1,460	1,422	none	none
Sussex	1,795	2,070	1,798	none	none
TOTAL	3,705	8,760	3,750	15,800	18,800
			AVERAGE		
New Castle	540	3,230	467	10,300	13,030
Kent	1,370	952	988	none	none
Sussex	1,795	1,006	904	none	none
TOTAL	3,705	5,188	2,359	10,300	13,030
			30-DAY MAXIMUM		
New Castle	540	5,230	530	15,800	18,800
Kent	1,370	1,460	1,422	none	none
Sussex	1,795	2,070	1,798	none	none
TOTAL	3,705	8,760	3,750	15,800	18,800

*Assumed 50 gpcd for those not receiving municipal water

TABLE 3 - GROUND WATER INVENTORY - 1957
STATE OF DELAWARE

County	Industrial, gpm	Public,* gpm	Irrigation, gpm	Misc. Uses,** gpm
		MAXIMUM		
New Castle	17,405	5,770	See surf.	1,478
Kent	19,665	2,830	"	4,430
Sussex	24,779	3,865	"	1,995
Total	61,849	12,465	"	7,903
		AVERAGE		
New Castle	8,917	3,770	See surf.	777
Kent	11,526	2,322	"	2,465
Sussex	17,102	2,801	"	510
Total	37,545	8,893	"	3,752
		30-DAY MAXIMUM		
New Castle	13,127	5,770	See Surf.	1,230
Kent	16,124	2,830	"	2,465
Sussex	20,970	3,865	"	535
Total	50,221	12,465	"	4,230

* Includes rural wells ** Includes sources such as military installations not considered in other tabulations.

TABLE 4 - SURFACE WATER INVENTORY - 1957
STATE OF DELAWARE

County	Industrial, gpm	Irrigation,* gpm	Public, gpm
		MAXIMUM	
New Castle	666,956	77,175	15,800
Kent	6,570	168,075	none
Sussex	161,630	78,750	none
Total	835,156	324,000	15,800
		AVERAGE	
New Castle	436,394	670	10,300
Kent	4,250	1,425	none
Sussex	9[illegible],315	655	none
Total	535,959	2,750	10,300
		30-DAY MAXIMUM	
New Castle	522,081	17,150	15,800
Kent	5,070	37,350	none
Sussex	125,415	17,500	none
Total	652,566	72,000	15,800

* Includes ground water

TABLE 5 - SUMMARY WATER USE INVENTORY - 1957
STATE OF DELAWARE

Description	Maximum, gpm	Average, gpm	30-day maximum. gpm
Ind. surface	835,156	535,959	652,566
Ind. ground	61,849	37,545	50,221
Munic. surface	15,800	10,300	15,300
Munic. ground	20,368	12,645	16,695
Irrigation ground & surface	324,000	6,000	72,000
Total	1,257,173	602,449	807,282

Whenever a municipal system supplied both the domestic and industrial needs, a segregation was made so that the tabulations recorded would show a true domestic use and a true industrial use. The water provided for domestic and/or industrial uses is accurately recorded in the larger municipal water systems. Where industrial needs are supplied from a municipal system in the smaller communities, estimates were made on the basis that 70 gal./capita/day is the normal domestic need and the balance was assumed as industrial water. However, this latter segregation constitutes only a very small percentage of the total, and the estimates applied to industry or domestic use do not materially affect the overall pattern.

The 30-day Maximum tabulations reflect water use during the dry weather periods. A significant percentage of this 30-day Maximum appears as irrigation water. The irrigation water use for 1957 has been tabulated to show the instantaneous maximum in any one day; the average application during a 30-day period and also the average use over a period of 365 days.

The purpose of this section on water use is to present the non-consumptive uses of water by commercial and industrial uses. However, irrigation, domestic, and miscellaneous uses are included for comparative purposes and will be discussed accordingly.

The industrial water inventory (Table 1) presents the total water-take by industry for Maximum demand (with limitations indicated above), the Average and the 30-day Maximum periods. No surface water sources are supplied by public utilities in Kent and Sussex Counties. The terrain is so flat in these lower counties and the tributaries so small that a safe and reliable yield of water for municipal needs is not practical. It is possible, however, that the Nanticoke River drainage basin could be used, after treatment, as a surface water source. However, none is being taken from this stream for domestic use at the present time. Ground-water resources in New Castle County

are small compared to those of the lower counties. The comparatively high ground-water figures for New Castle County taken from private sources consist primarily of well water from the Tidewater Refinery. The surface water totals for industry from public sources are derived primarily from the Wilmington Water Department and the Delaware Water Company. The surface water totals from private sources are primarily steam generation and industrial cooling waters. In New Castle County the major uses are the Tidewater Refinery and the Delaware Power and Light. In Sussex County the reasonably high surface water withdrawals are for steam generation and industrial cooling at Millsboro, Laurel, Seaford, and the duPont Nylon Plant. The municipal water inventory (Table 2) shows a greater supply being delivered to industry than to the public from municipal surface sources.

The total ground-water inventory shown in Table 3 is a composite-type table which includes the tabulations presented in Tables 1 and 2. The industrial and public tabulations show the total of both the private and the public ground-water sources supplying water to industry. The section designated as Public represents all waters supplied for domestic needs from ground-water sources. Miscellaneous uses include, as pointed out previously, the waters supplied to the military installations and State institutions. These include such installations as the Dover Air Force Base, the New Castle Airport, Governor Bacon Health Center, and other State institutions. The 30-day Maximum tabulations show that the total industrial ground-water withdrawals constitute 54.1 mgd. Public water from ground sources total 12.81 mgd, and miscellaneous uses 5.41 mgd.

The surface water inventory, as shown in Table 4, is also a composite-type table including totals from Tables 1 and 2. Several significant facts can be brought out from these tabulations. The 30-day Maximum summation of the industrial uses total 943 mgd. A major portion of this total is steam generation use and industrial cooling water. Attention is directed towards the irrigation listings. Quite significant is the fact that the instantaneous maximum in any one day of irrigation use during 1957 constituted one-fourth of all water use in the State of Delaware, including steam generation and industrial cooling. This figure is most significant, in that it shows the relationship of irrigation needs as compared to other water usages. Even the 30-day Maximum of 103 mgd becomes very much a major use. The 30-day Maximum irrigation water use is 400% greater than all the water used for domestic purposes in the State of Delaware.

The total summary water use for the State of Delaware during 1957 is shown in Table 5, and combines all the tabulations as presented in the previous four tables but in a more concise manner. The Average total for all water uses in the State of Delaware is 602,449 gpm or approximately 867 mgd. This may be compared to the more significant 30-day Maximum of 807,282 gpm or 1162 mgd. The greatest water use is from surface sources (Table 5). Of the 30-day Maximum use 75.6% is industrial cooling and steam generation.

Table 6 shows a different presentation of the total summary of water use, including cooling and steam generation, as of 1958. In this presentation water use is divided into "In-basin" and "Out-of basin" segments. It is significant to note that in New Castle County there is essentially no out-of-basin uses. In Kent County, for all practicable considerations, the same conclusion may be drawn. In Sussex County, however, there is a significant amount of out-of-basin withdrawal, primarily in the form of cooling water from the Nanticoke Drainage Basin.

In Table 7 the same approach is used as in Table 6, except that this presentation deletes cooling and steam generation waters In New Castle County there is essentially no water that may be considered as out-of-basin. Similarly, Kent County has essentially no water out of the Delaware River Basin. In Sussex County the percentage out-of-basin was considerably reduced to approximately 25% of the total use in the County.

For comparative purposes, Table 8 presents the cooling and steam generation waters for industry separated into fresh and brackish sources. This is also broken down to show the portion that is out of the basin. It is quite clear that only a small percentage of the total cooling and steam generation waters in the State of Delaware are taken from out-of-basin sources.

In summation of Tables 6, 7, and 8, it can be seen that the total industrial water use within the Delaware River Basin totals 827 mgd. Industrial water use, excluding steam generation in the Delaware River Basin, totals only a 104 mgd. Further, of the total industrial in-basin use, 87.4% is cooling water.

The cooling and steam generation water withdrawn in the State of Delaware in 1958 totaled 887 mgd. Of this total, 153 mgd was fresh water and 73 mgd brackish. A breakdown of this total shows the out-of-basin cooling use was approximately 87 mgd fresh and 77.6 brackish, or a total of 164.4 mgd. By difference, the fresh in-basin use amounted to 66.75 mgd and the brackish totaled 655.9 mgd with a total in-basin cooling use of 722.65 mgd. Consequently, of the total in-basin cooling use 90.7% was brackish. Therefore, of the total in-basin industrial use of 827.54 mgd, the brackish water withdrawn totaled 655.9 mgd or 79.2%. The industrial ground water withdrawn in 1958 reached 70.8 mgd. Consequently, the total surface water withdrawn from brackish areas constitutes 88.0% of the surface water used for cooling purposes.

TABLE 6 TOTAL SUMMARY WATER USE
INCLUDING COOLING & STEAM GENERATION - 1958

	New Castle			Kent			Sussex		
Desc.	Total	In Basin	Out of Basin	Total	In Basin	Out of Basin	Total	In Basin	Out of Basin
Ind.	772	772	-	30.5	29.84	.66	211.0	25.7	185.3
Mun.	32.8	32.8	-	7.63	7.63		6.34	6.34	
Irri.	24.65	24.65	-	53.80	53.80		25.35	25.35	
TOTAL	829.45	829.45	-	91.9[illegible]	91.93		242.69	242.69	

TABLE 7 WITHOUT COOLING & STEAM GENERATION WATERS - 1958

	New Castle			Kent			Sussex		
Desc.	Total	In Basin	Out of Basin	Total	In Basin	Out of Basin	Total	In Basin	Out of Basin
Ind.	71.0	71.0	-	23.35	22.69	.66	31.45	10.85	20.60
Mun.	32.8	32.8	-	7.63	7.63		6.34	6.34	
Irri.	24.65	24.65	-	53.80	53.80		25.35	25.35	
TOTAL	128.45	128.45	-	84.78	84.78		63.14	63.14	

TABLE 8 COOLING AND STEAM GENERATION - WATERS
INDUSTRIAL - 1958

Description	New Castle	(TOTAL) Kent	Sussex	Total's
Fresh Water	59.60	7.15	86.80	153.55
Brackish	640.00	-	93.50	733.50
TOTAL	699.60	7.15	180.30	887.05
		(OUT OF BASIN)		
Fresh Water	-	-	86.80	86.80
Brackish	-	-	77.60	77.60
TOTAL	-	-	164.40	164.40

18-06. EVALUATION OF NUCLEAR WASTE DISPOSAL PROBLEMS

a. General Introduction. Public Law 703, 83rd Congress, approved August 30, 1954, known as the Atomic Energy Act of 1954, greatly enlarged the opportunities for peacetime uses of atomic energy. The Act provides for research in atomic energy and its applications, authorizes the licensing of facilities to utilize atomic energy, and specifies various restrictions on the use of radioactive materials and their by-products. However, with increasing peacetime use of radioactive materials, confined use is changed to one of widespread use and the associated problems of control, specifically waste treatment, becomes a major issue.

Being fully cognizant of this burden, many individuals, companies, and associations interested in the peacetime use of atomic energy are giving considerable attention to the disposal of radioactive wastes (40). It is universally accepted that all radioactive wastes must be disposed of in an acceptable manner. Since the early days of the Manhattan District projects, improvements have been made upon treatment and disposal of sewage and industrial wastes containing radioactivity. The environment of an operation plays a large part in the disposal of radioactive wastes. Nearby uses of air and water containing radioactive wastes require more stringent removal of these wastes before discharge. Industries have initiated practices to protect both employees and the inhabitants of the surrounding area from radiation exposure in excess of recommended national limits. Similar to the text Standard Methods for water and sewage treatment, the atomic energy industry has developed units and methods of analyses to evaluate the exposure to radiation. Since all living things can be affected by radiation, the potential hazard of radioactive wastes is one of the primary bases used in establishing what should be done with the wastes. Intelligent evaluation involves an understanding of, and appreciation of, the radiological, biological, physical, and chemical factors of each radioisotope or group of radioisotopes. Personnel must be adequately protected against exposure from the wastes. Standards must be established, based on the best information available. Routine analytical surveys must be made to determine whether the standards are met. Specially trained personnel are required to handle analytical equipment, make necessary calculations, and to interpret the results. Governmental agencies establish rules and regulations to provide adequate control of atomic energy and protection against radiation. These would be directly applicable to radioactive waste disposal problems also.

There are several schools of thought as to how much can be accomplished through laws and regulations governing disposal of radioactive wastes on a state or national basis. The type of law or regulation may limit the degree of effectiveness. One might set up narrow limits and conditions which could not be exceeded under any circumstances. Another might be designed, primarily, for the purpose of establishing a broad policy. It is difficult to make a code in such a relatively new technical field and when new information is being developed daily. It might be better to continue the present practices under which standards are determined from the best available information,

research, and development rather than to attempt a detailed codification. Standards and limits may then be adjusted as new knowledge becomes available. It is usually easier to revise a manual or handbook than to change a legal code by due process of law. The discussion of radioactive wastes disposal was a major part of the program of the International Conference on Peaceful Uses of the Atom, held in Geneva during August 1955. Such exchanges of information on the international level must be followed by exchanges on the local level, such as water and sewage plant operators organizations.

b. Problems of Control Agencies. State governments are facing a grave challenge in providing adequate control to prevent harmful radiation exposure in the environment (36). Personnel, equipment, and a period of time in which to develop competence are basic to any successful program. Generally, it appears that much has yet to be done to cope with the booming problems adequately.

The potential benefits of atomic energy should be fully recognized. The goal should be the attainment of radiation protection with minimum restriction on the early development and utilization of these benefits. However, the burden is still great for those who are responsible for assuring the safety of our environment.

Emphasis is usually placed on two factors: (a) the anticipated increase of the use of nuclear materials (for example, by reference to the creation of millions of curies of new fission products by power reactors), and (b) the unknown effects of radiation on human beings. Of even greater importance from the standpoint of state government is the magnitude and complexity of the task faced during the current transition stage as the emphasis on atoms for peace shifts the responsibility for development from the Federal Government to the private industry. As this occurs, the states in discharging their traditional responsibility for protection of their environment, will have to assume a major role in a program of radiation protection. There is a real question as to the readiness of many states to accept this challenge. The Federal Government has achieved a remarkable success in the control of radiation so far despite its early "crash type" programs. Now the problem is being handed over to industry, etc. Federal controls are available, but it remains to be seen how successful these controls will be in the hands of private industry.

Many new factors must be considered in relation to utilizing watercourses for radioactive waste disposal (36). They include the following:

(1) Tremendous volumes would be required for dilution of the radioactive wastes. It has been estimated that a million times more dilution is needed than for present pollutional material. One billionth of a part per million of strontium 90 is the tolerance level.

(2) The food chain is a prominent factor. Plankton and algae

absorb the radioactive nutrients directly from the water; bottom animals feed on them; fish feed on the animals; and finally man feeds on the fish. Also, some plants and organisms (as shellfish and barnacles) concentrate radioactivity in certain portions. Oysters could be used as "index" organisms for "build up" studies. In fact, they would be ideal: sessile, large and accumulate. If this is ingested, it involves a dose much greater than that anticipated by the dilution. Contamination from radioactive wastes may be a greater threat to the oyster industry than river flow problems. Indeed, regardless of optimum conditions (for growth and reproduction), radioactivity in the estuary is the death knell for shellfisheries.

(3) Thermal and density stream flow patterns near discharge must be studied and known thoroughly.

(4) Time is essentially the only factor affecting any reduction in the radioactivity of material remaining in suspension.

(5) Radioactive sediments may cause buildups at low flow and resuspension during flood flows.

For nuclear energy plants, water supply presents a serious problem (36). Particulate matter must be excluded entirely, as it is easily irradiated, which would present a problem downstream. Disposal of radioactive wastes in the municipal sewer systems and eventually treatment works will present other problems. It is believed that these will be small because the larger sources will handle their wastes independently. However, difficulties may be experienced in such matters as (a) concentration of radioactivity in the biota of the sewer, (b) removal efficiencies at the treatment plants, (c) possible concentration in some units of the treatment works, (d) effects beyond the outfall, and (e) personnel safety. This will involve elimination or prevention of sources of wastes, routine monitoring, and possibly adjustment of treatment processes.

The evaluation of a radioactive water pollution problem requires knowledge of a natural background radiation, the characteristics of the radioactivity present, and information on the kinds of radioisotopes from the sources of contamination. The work associated with such an evaluation is immense. Moreover, the problem is one of great complexity and is made more complex by the fact that many of the involved procedures are yet to be developed or refined. It will definitely be the responsibility of sanitary engineers to join with other scientists in accomplishing this work in the same way that they have helped with other wastes disposal problems.

From a public health standpoint (20) it is necessary to consider exposure to increasing radioactivity due to both natural and man-made sources. Presently, natural radioactivity is not recognized as a limiting factor. However, there is increased interest in the background radioactivity in relation to the health aspects of increased radiation.

Radioactive background in natural waters is in the range of 10^{-9} to 10^{-6} microcuries per ml. This background is gradually being raised by atomic detonations, and it fluctuates from day to day due to many factors (natural). Maximum permissible levels for some isotopes fall within these ranges. Thus, it is easy to confuse the background radioactivity with discharges from an atomic industry.

Consideration is now being given to standards based on total exposure from both artificial and natural sources rather than from additions to the background alone. Standard techniques for radiation assessment must be developed which are capable of interpretation and reporting in a uniform manner. This will include the development of sampling methods (number, types, sizes, locations, frequencies) meeting statistical and other requirements for reliability and significance. Uniform reporting procedures must be developed, and evaluation of results must be such as to be interpreted in terms of public health significance.

There are many types and qualities of radioactive material which are a potential waste. These must be considered in terms of such groupings as sources, activity levels, chemical and physical properties, operating methods, and industrial and regulatory limitations. Concurrently, constant efforts must be made to evaluate the individual situation in terms of the total radiation exposure to the population and the economic consideration. Over the long term, the growth of nuclear industry, medical, and military applications, when compared with current health standards, easily justifies an alert attitude on the part of industry and governmental agencies. With this growth, research and development should provide practical and more economical solutions to specific potential hazards. Waste handling, treatment, disposal, and evaluation must be given a high priority by industry and government if the receiving waters of the nation are to be properly protected from hazardous radioactive contamination levels.

The first civilian nuclear power plant in the U. S. is located at Shippingport, Pennsylvania, with a 60,000 kilowatt version of the pressurized water reactor. Like any industrial operation, the atomic energy industry (43) will produce wastes. These wastes are of particular concern because they are radioactive, and even at low concentrations radiations are damaging to living tissues. The problem of radioactive waste disposal may be considered in three parts:

(1) Control of the quantities released.

(2) Knowledge of the behavior of individual radioisotopes between the point of release and entrance into the human body.

(3) Knowledge of the behavior of individual radioisotopes in the human body.

Part (1) is primarily the problem of chemical engineering.

Part (2) involves such phenomena as dilution of the radioisotopes after release, possible seepage of the radioactive material into the water table or subterranean streams, and concentration of chemical elements, a physical process in plant and animal life. Part (3) includes the effects of the various radiations on body tissues and body uptake, distribution, and excretion.

Radioisotopes have found wide usage in research, medicine, and industry (43). Generally, small amounts (micro-and millicurie quantities) of single radioisotopes are used in tracer experiments and the waste volumes resulting are small with a low radioactivity. Larger quantities both in volume and radioactivity may be discharged from hospitals. Guides have been prepared for the disposal of specific radioactive materials. Since the quantities of radioactivity involved are generally small, the simplest method of disposal is into a sewer system. A 1954 survey showed that 41% of the 1,027 users of radioactive materials disposed of their radioactive wastes by dilution and discharge into sewers. Another method proposed involves dilution with a stable element of the same form as the radioactive one. Care must be taken to avoid the creation of a chemical toxicity problem if this method is used.

Nuclear power reactors have the greatest potential as a source of large amounts of radioactive wastes (43). Concentrations of up to several hundred curies per gallon may result from the processing of fuel elements taken from nuclear power reactors. It has been estimated by 1965 there will have been constructed some 5 million kilowatts of nuclear power capability; by 1970, 27 million; by 1975, 83 million; and by 1980, 175 million kilowatts. The amount of radioactivity remaining in the fuel element of a fission reactor is known. From the 1965 figures, we could expect 6.1×10^6 grams of fission products to be used, which at the end of one year would have a power level of 6.1×10^6 watts. Since one watt is equivalent to 500 curies, the total quantity of radioactivity in 1965 would be 3×10^9 curies. In 1980 this would be 1.05×10^{11} curies per year. For comparison purposes, this is roughly twice the quantity of all the radioactivity in the oceans of the earth. The fission yield for strontium 90 is 5.3%. In 1980, the essential fission product production would require in the area of 1×10^{16} to 2×10^{18} gallons of water to dilute the strontium 90 to safe drinking water levels. The lower figure is a more recent calculation.

In dealing with and handling radioisotopes, the ideal objective is to retain absolute control of all radioactive waste materials as near as possible to their source of production (43). Since this is generally impossible, the practical goal is that of preventing damage to human tissues, and in some instances, of preventing economic waste. This goal may be reached by the judicious application of the criterion that external and internal dosages to plant operation personnel shall not exceed 0.3 roentgen equivalents man (rem) per week, and its corollary that the concentrations of radioactive materials in air or water shall not exceed the published maximum permissible concentration (MPC) values.

In the case of long continued exposure and/or release of contaminant beyond the plant area, it may be desirable to use 1/10 of the values cited above. The actual limiting concentration should be determined by the composition of the individual radionuclides present. In lieu of this, the maximum level of 10^{-7} microcurie per ml may be used for mixtures of radioisotopes. The identification of the radioactive isotopes present is not too difficult if the number of individuals is small and the concentration in terms of radioactivity is high. In the case of low concentrations of radioactivity, such as in surface water at the present time, identification is difficult and becomes increasingly difficult as the number of radionuclides in the mixture increases. Another difficulty is that radiochemical procedures for identification of the radionuclides present at these low levels are not available. So far procedures for strontium and barium have been published and those for other isotopes such as cesium, zirconium, niobium, cerium, yttrium, iodine and rutheium, are to be released shortly. By showing that these more critical radionuclides are not present, the quantity of radioactive materials being discharged may be increased by a factor of 100 or more over the presently accepted MPC value of 10^{-7} microcuries per ml. With these analytical procedures, the scientist will be in a better position to follow the movement of radioactive materials downstream from their point of discharge and to observe the effect of natural agents on their removal. A better understanding of what takes place in the sewer, the sewage treatment plant, and the streams will be of considerable value in defining the permissible discharges.

In general, two principles are employed in radioactive wastes disposal (43); dilution and release, or concentration and storage. Treatment of these wastes differs from the treatment of other waste materials. All that can be done is to transfer the radioactivity from one phase to another, as from liquid to solids. Only time will render the wastes innocuous, and the time necessary for this to take place varies with the half-life of the material. Strontium is of a major concern because it is deposited in the bone structure of man where it remains radioactive for many years. It has a long physical half-life of about 20 years. The slow rate of elimination from the body, with a long biological half-life of 10.7 years, thus exposes bone tissues over an extended period of time.

The control of radioactive waste discharges to surface waters is a problem similar to that encountered in the control of any other industrial wastes (46). The difference is chiefly in analytical methods. Although these wastes involve a very direct public health hazard, state water pollution control agencies have been dealing routinely with similar problems for some time. The same control measures are generally applicable However, the anticipated great size of this industry and the circumstances responsible for this early development, require both Federal and State regulations. With radioactive pollution, it is even more desirable to control the pollution on a basin-wide approach A basin-wide list of all the users of radioactive materials should be developed and should include Federal as well as private and other sources Such a list kept current can

serve as a sound basis for basin-wide pollution control. Effective control of pollution requires that the State and local regulatory agencies concern themselves with a potential pollution source in the very early stages of planning. This is especially important regarding radioactive wastes sources.

Each proposed new source of radioactive pollution should be studied in regards to:

(1) Proper site selection

(2) Kinds and quantities of wastes involved

(3) Consequences of accidental discharge

(4) Downstream water uses

(5) Adequacy of proposed treatment and precaution

(6) Other influencing factors

Water monitoring after the discharge of the wastes is too late to provide adequate protection, and these bases for examination should be necessary condition for approval before the installation of the industry. Where major quantities of radioactivity are involved, consideration should be made of emergency planning for potential accidents in each case. Direct and rapid communication with management should be a part of such a plan

Radioactivity measurements in natural waters should include a study of the water, biological life, and the river mud or silt samples. Grab samples of river water will provide an instantaneous picture of stream water quality. Above any source of radioactive wastes, a reasonable number of samples can yield an estimate of background radioactivity. Radioactivity downstream may vary hourly and daily,and composite samples should be taken over a period of time. Taken alone, grab samples downstream are not representative of water quality. River biota and mud samples reflect a cumulative condition, rather than a momentary condition. The stream biota will take up and selectively concentrate certain chemical elements in the course of their metabolic activities. The degree of concentration will depend upon the element, its chemical form, as well as the environment factors. Biological samples can yield a cumulative picture of stream quality in terms of radioactivity representing a relatively long period of time.

River mud samples may reflect many weeks of accumulation of insoluble suspended radioactivity, depending upon the hydraulic characteristics and flow of the stream. Normal background radioactivity in the streamsof a basin, contained in the 3 types of samples, discussed above, is necessary for the purpose of controlling pollutional sources,

and should be obtained as soon as possible. Presently employed standards for permissible amounts of radioactivity in water refer to amounts above the normal background or to the amount which can be added rather than the total radioactivity content. These standards are not greatly in excess of natural background levels. Standards for specific radioisotopes refer to total amounts rather than to additions to the natural background. In order to apply standards properly, it is necessary to determine the normal background, which must be obtained before pollution starts. The regulatory agency should have at its disposal prior knowledge of existing users of radioisotopes and the type of wastes that are involved. This will aid in selection of stations for background as well as control information. In addition, the establishment of a water monitoring program, by the state, can do much to dispel public fear and apprehension. Indiscriminate stream monitoring is not suggested. Just as for proper pollution surveys, monitoring should be specific as to location and to purpose. The state control agencies are best able to plan such action.

Measurements of gross radioactivity, alone, cannot always be adequate for purposes of pollution control (46). When gross radioactivity levels equal or exceed permissible limits, it is necessary, whenever possible, to identify and measure the most important specific radioisotopes involved. For instance, radium has been indicated as a source in the case of uranium mill wastes. Strontium and cesium are specific radioisotopes of importance as fission products, and occur in connection with reactor wastes. Radio-phosphorous has been identified also as an important waste product of reactors. Therefore, effective radioactive waste control will at times require identification and separate measurement of specific radioisotopes in a mixture. As both biological and river mud samples are accumulative by nature, they will contain more radioactive material than water samples. For the purpose of specific radioisotope identification and measurement, they offer a more fruitful source of information than do the water samples.

Experimental research is still in full force to determine the take-up of radioactive material by living organisms and the physiological effect upon humans (46). Therefore, standards established should be subject to constant revision. A handbook has been prepared (47) with standards for continuous lifetime exposure, rather than for short term discharges of concentrations. The National Committee on Radiation Protection has stated in this hand-book the following excellent philosophy: "Because of the many uncertainties involved, the Committee recommends that every effort be made to keep the concentrations of radioisotopes in air and water and in the body to a minimum. The goal should be no radioactive contamination of the air and water and of the body if it can be accomplished by reasonable expense and effort If such a goal cannot be obtained, the average operating levels should be kept as far below these recommended values as possible, and not above them for any extended periods of time."

c. Concentration. The concentration of radioactivity in sewage receiving radioactivity from hospitals, universities, etc., is in the range of 10^{-6} microcuries per cc. (37). This is not sufficient to endanger sewer workers, plumbers, or other maintenance personnel, or to cause any injury to bacteria. To receive the maximum permissible weekly radiation dose, the worker would have to be completely immersed for about 9 minutes in sewage containing about 0.1 microcurie per cc. In all cases of record, the radioactivity of raw sewage receiving radioisotopes from these sources is even lower than the level considered safe for potable water.

An example of standards applicable for the disposal of radioactive wastes into public sewers include the following (24):

(1) The commission must authorize any disposal of licensed radioactive material. Licensed material may be disposed into the sewers provided that the material is soluble.

(2) Radioactive levels include the following: strontium 90 or polonium 210, not to exceed 1 millicurie per million gallons; iodine 131 or phosphorous 32 or any radioactive material having a half-life of less than 30 days, 100 millicuries per million gallons; any other radioactive material, 10 millicuries per million gallons.

(3) Dilution of radioactive isotopes with stable isotopes of the same element in the same chemical form may be discharged so long as they are diluted and homogeneously mixed and the radioactivity does not exceed 300 millirems per week. This latter regulation is also satisfactory for burial in soil or in the ocean.

d. Theory of Effects on Waste Stabilization. Studies were made (41) of the effect of radio-phosphorous upon BOD, using the Warburg Apparatus. Using full strength synthetic sewage, radio-phosphorous in concentrations up through 50 millicuries per liter, showed no significant effect upon bio-chemical oxidation. Inhibition was observed with concentrations of 60 and 80 millicuries per liter. No significant variation was found in the presence of up to 80 millicuries per liter of radioactive phosphorous, with full strength domestic sewage. In 20% mixtures of synthetic and domestic sewages, up to 60 millicuries per liter of radio-phosphorous had no effect upon the oxidation of either.

In the first stage of the BOD curve (32) phosphorous 32, in concentrations up to 10 millicuries per liter, had very little effect upon the rate constant oxygen utilization. However, this concentration reduced the nitrite and nitrate production sharply. The presence of iodine 131, in even 0.01 millicuries per liter definitely reduced the BOD values. The iodine also reduced the formation of nitrite and nitrate.

Laboratory experiments were designed (25) to investigate the fate of 5 commonly used radioisotopes (sodium 24, phosphorous 32, and cobalt 60, chromium 82, iodine 131) during the characteristic processes of sewage treatment, including primary sedimentation, percolating filters, and activated sludge. Absorption in trickling filters and the activated sludge process is similar, being little for sodium 24, bromine 82, and iodine 131, and greater for phosphorous 32 and cobalt 60. Studies with phosphorous 32 on percolating filters failed to reveal any measurable radiation effects at a radioactive concentration of 100 millicuries per liter on the microorganisms responsible for sewage purification.

e. Treatment of Radioactive Wastes.

(1) Conventional sewage treatment process. Rubidium 86 was added to a trickling filter and the concentrations in the influent and effluent were recorded (30). The results showed an absorption of the radio-isotopes within the filter bed and a slow leeching over a period of about 37 hours after dosage. The absorbed radioactivity was associated with the zoogleal mass growing on the filter rock.

Test runs on slow sand filters (28) showed that this affords little protection to the consumer of drinking water against contamination by rubidium 106, strontium 90, and iodine 131. In activated sludge studies, a different optimum pH for removal of each radioactive contaminant was found. Cerium was the most effectively removed, cesium and ruthenium the least. About 96% plutonium was removed in 24 hours. The activated sludge process is not likely to compete in reliability or efficiency with chemical methods. However, biological treatment of effluents otherwise requiring such treatment to remove organic matter would, in many cases, result in a useful reduction in activity. Biological treatment might also find application in treatment of effluents not amenable to treatment by purely chemical methods, such as those containing organic complexes of radioisotopes.

Activated sludge and trickling filter processes were found to remove 70% to 85% of fission products, 1 to 3 years old (33). Generally, the removal of strontium did not exceed 20% and depended upon the mineral composition of the sewage. In sewage oxidation ponds, the most effective method for separating radioactive contaminated organisms and associated debris was by filtration through diatomaceous earth. The cost was 15 cents per 1000 gallons.

(2) Precipitation. Chemical precipitation and settling with subsequent filtration was expensive and the removal was not as effective as vacuum filtration through diatomaceous earth (33).

Radioactive strontium can be co-precipitated with calcium carbonate as mixed crystals in the cold lime soda process (34). Maximum reduction of calcium hardness is essential for the maximum strontium removal of 50%. Repeated precipitations with calcium carbonate will remove more than 99% of the radio-strontium.

Studies were made (33) of coagulation with ferrous sulfate, lime, and phosphate, with and without clay and silt additions, for removal of strontium and mixed fission products. Depending upon the type of contamination, the kind and amount of chemical agents, and the pH of coagulation, the removal varied from 60 to over 95%. Very little radioactive strontium was removed in normal water treatment by coagulation. A higher proportion was removed with an excess dose of coagulant. Ion exchange softening removed over 97%. Studies with slow sand filters showed that the initial removal was relatively high until equilibrium was reached in one-half to 5 or more days depending upon the isotope. At equilibrium very little strontium 90 and ruthenium 106 were removed. About 50% of the iodine 131, 90% of the plutonium, and over 99% of the cerium 144 were removed.

Precipitation of radioactive wastes can be achieved in several ways (35). Cocrystallization with ammonia alum for the recovery of kilocurie amounts of cesium was practiced. Strontium, ruthenium, and rare earths were precipitated in kilocurie amounts as hydroxides and carbonates on ferric hydroxide carrier. A ferric hydroxide manganese dioxide scavenging precipitation was found effective for removing 90% of the niobium, and 95% of ruthenium and zirconium in a contaminated waste high in aluminum nitrate and nitric acid.

(3) Ion Exchange. The water used for cooling aluminum clad fuel elements in an atomic power generator must be of the highest purity (26). Total solids in excess of 0.5 milligrams per liter of cooling water results in the solids becoming so radioactive as to require shielding of the water system for personnel protection. Some of the primary cooling water is continuously recirculated through 2-bed ion exchange units. When these units are exhausted they are sufficiently radioactive to require discard by burial.

Low level radioactivity can be removed by sulfonic acid cation exchange resin (44). Although only 6,000 gal. per cu.ft. can be tolerated by the resin before hardness breaks through, at least 260 000 gallons can be passed through 1 cu.ft. with 80% reduction in radioactivity.

Partial decontamination of radioactive wastes is achieved in a multicompartment membrane cell of the same type used for producing potable water from salt water (48). This is followed by decontamination in another multicompartment permselective cell modified with a mixed resin granular bed exchanger in the deionization compartments in order to remove the ions without the use of chemicals. Power consumption is too great for a high degree of purity in the waste stream unless the mixed bed exchanger is used The concentrated waste is the evaporated.

Experiments were performed (33) on the retention of radioactive wastes in shale by percolation through small columns and by shaking with clay suspensions. Under laboratory conditions 98 to 100% of barium 140, cerium 144, cesium 137, phosphorous 132, ruthenium 186, and zirconium 195, were removed. Only 80% of the strontium 90 was removed. The chemical form of the isotope affects removal.

(4) Biological.

Oxidation ponds are in common use in the Southwest and particularly in Texas where investigations (42) were performed to determine the uptake of radioactive isotopes, including iodine 131, phosphorous 32, strontium 89, cesium 137, cerium 141, and mixed fission products. The maximum removal of iodine 131 was about 20% and the mean uptake over a period of two weeks was about 5%. In aquarium experiments, uptake by algae and bacteria or precipitation was 5 to 20%. The phosphorous 32 uptake is dependent upon the concentration of available stable phosphorous in the system, and the rate of biological growth. The average uptake of cesium 137 and its radioactive daughter barium 137, was less than 10%.

A mixed fission product was added to the first of a series of 3 oxidation ponds. Eighteen days later the maximum concentration was found in the third pond. This showed a reduction of about 96% in gross radiation. Gross radiation is the total of suspended and soluble. Of this about 60% was recovered in the sediment after centrifuging; however, after the ponds were drained, considerable sediment was noted on the bottom. This was found quite high in radioactivity. On several occasions scum floated to the surface of the first pond and contained considerable amounts of radioactive isotopes. After six months there was apparently a gradual release of radioactivity. Strontium isotopes must be separated from a waste if any disposal of mixed fission products is to be successful. Approximately 70% of the strontium 89 was removed in a 20-day detention period. In 15 days detention, approximately 95% of the cesium 141 was removed. The mechanism of removable is likely to be very erratic and may vary from fluctuations in light, temperature, pH, nature and concentration of nutrients, and rate of growth.

The concentration of radioactivity in bottom sediments presents a problem. It is recommended that concrete bottom tanks be provided with sludge removal facilities. Any disturbance of the radioactive benthic sludges might redistribute concentrated radioactivity into solution. Circulation with filtration might also lessen the bottom deposits.

Studies were made of the uptake of radioactivity by two specific organisms (35). It was found that overall removal of one-half to two-thirds of the radioactivity was achieved in 6 days. However, after 12 days the settled dead organisms decomposed and released part of the absorbed radioactivity.

(5) Specific Compounds.

Treatment (34) of highly radioactive aluminum nitrate wastes with ferric hydroxide manganic hydroxide ($Fe(OH)_3$ MnO_2) removed more than 90% of the Niobium, Ruthenium, and Zirconium. Co-precipitation studies showed that ruthenium and cesium were precipitated with copper ferrocyanide ($Cu_2Fe(CN)_6$), strontium with barium sulfate, zirconium and niobium with zirconium oxide hydro-phosphate ($ZrO(H_2PO_4)_2$), and the rare earths and yttrium with cerium oxalate ($Ce_2(C_2O_4)_3$). A removal of 95% of the activity was obtained with a waste volume reduction of 20 to 1, at a chemical cost of 1.5 cents per liter. A sulfonic acid type cation exchange resin can remove 75 to 80% of the beta-gamma activity.

One-and two-stage trickling filters were used for treating laundry wastes containing fission products or other isotopes (34). Under optimum conditions, percentage removals were; strontium 89, ruthenium 79, zirconium 79, yttrium 87, cesium 97, and fission products 90.

Single or two-stage trickling filters operated continually at organic loadings of 250 lbs. BOD per acre-ft. per day (35), removed about 90% of gross fission product from laundry wastes. Removals were as follows: cesium 97.3%, rubidium 79.1%, strontium 69.4%, iodine 86.7%, zirconium and niobium 79.5%.

Clay suspensions of 2500 to 5000 ppm are capable of removing about 90% of added cobalt 60, zinc 65, selenium 75, tantalum 185, irridium 192, thallium 204, in 30 minutes, and a dose of 1000 ppm clay is quite effective for removing cerium 141, cerium 144, zirconium 95, niobium 95, calcium 140, lanthanum 140, and strontium 90, yttrium 90. Clay was less effective for ruthenium 106, rhodium 106, and very poor for iodine 131. The removal was not affected by calcium concentration but improved at pH above 5 (33).

Many varied means of treatment of wastes containing radioactive materials have been studied. Optimum conditions for removal depend upon the specific radioactive material present and the type of waste to be treated. In most instances a satisfactory means for treatment can be found. In some cases removal of the radioactivity can be achieved only through considerable expense.

(f) Disposal. Suggested disposal methods for these highly radioactive wastes include disposal into deep wells, salt domes, or salt strata, hydrologic basins or troughs, and coastal formations on the salt water side of the interface between the salt water and the fresh water, as well as ocean disposal (43). However, the latter would require a very carefully studied evaluation.

Sea burial of solidified and encased radioactive wastes can be practiced in very limited areas of the sea floor (36). They must be deposited in muddy areas where they will sink into the mud and remain

permanent. Due to a general lack of quantitative data or pertinent oceanographic factors, and the high cost and complex technical problems involved in preparing, handling, and transporting high level wastes to a suitable point of disposal, the possibilities of ocean disposal are not as good at present as those envisioned for land disposal (43). Another solution is the fixation of the radioactivity in montmorillonite clay which is then heated to about 800°C. and glazed. These are impervious to leakage (22) and therefore suitable for disposal in the ground or in the ocean. The Oak Ridge National Laboratory (43) is investigating the possibility of utilizing the waste heat from the radioactive decay for fusing and fixing the radioactivity in these bricks.

A presently accepted method for handling high level waste materials is storage (31). With a purex type of fuel recovery process and mechanical dejacketing of the fuel elements, about 20,000 gallons of highly radioactive wastes would be produced by irradiation of natural or slightly enriched uranium to about 2500 megawatt days per ton. The wastes would be expected to self boil for perhaps 50 years.

The feasibility of employing underground formations for the retention or permanent storage of radioactive wastes, is dependent upon: (a) the chemical and physical compatability of the wastes with the receiving formation, and (b) a degree of certainty of predicting the velocity and direction taken by the more hazardous components of the wastes (38). The first criterion is met if the waste is free of particles or chemicals which form precipitates when mixed with the soil and ground water. The second condition is more critical from the standpoint of public health and public relations and admittedly will be extremely difficult, if not impossible, to meet under all circumstances. However, it is believed that the geology of many areas, when examined together with the location of cities and water supplies, may offer a disposal resource about which the engineer may design a free discharge ground disposal system with the assurance that the wastes will not subsequently constitute a hazard to health or in any way impair the beneficial uses of ground or surface waters.

A process has been developed (35) for converting aqueous nuclear wastes to solid form by injection into a fluidized bed of heated solids, where evaporation and calcination of the wastes to oxides is effected. Another calcining operation has been described in which simulated highly radioactive waste streams containing salt were converted to anhydrous, free-flowing melts.

Ferrous sulfide and ferrous cyanide precipitation have been used (35) to precipitate radioactive wastes, followed by an absorbent. The removal of 97.9% was possible, and resulted in a low burial volume, compared to the original waste volume. Another method is to roast the completely evaporated wastes at 300°C. for an hour. This leaves behind cesium and strontium plus the other water insoluble oxides. Warm water dissolves the cesium and strontium nitrates. Ninety-five per cent of cesium and 85% strontium can be extracted. Studies show that precipitation

for the removal of radioactive substances results in less storage space to be provided for disposal, less elaborate storage, self boiling of the wastes is overcome, and there is no need for special tank cooling facilities. Electrodialysis has been used to concentrate weak ionic constituents. Concentration factors of 100 to 1 were obtained.

Ocean disposal studies (35) were conducted in the Irish Sea at Seascale, England. After 5 years, tests made on sea-weed, fish, and sea-bed mud showed no harm to marine or human life from the discharges of the relatively low level liquid wastes. Approximately 20 to 30 tons per year are disposed along the east coast and 4 to 5 tons on the west coast. No disposal of high level wastes is practiced at present.

A vapor compression evaporator (34) running at 300 gallons per hour can reduce the volume of radioactive wastes to 1 to 2% of the feed volume.

The Army Engineers (35) have a mobile unit which will decontaminate 3,000, 1500, or 600 gallons of water per hour of suspended or dissolved radioactivity by a factor of 10^3 with 99.9% reduction.

Experiments were conducted (35) involving incineration of combustible radioactive materials. There was no significant contamination of either the soil or the air under varying conditions. It is considered that this will be an excellent method for reducing the volume of radioactive waste to be disposed.

Various chemical precipitation processes for removing the hazardous radioisotopes have been tried with some success (43). Solvent extraction processes and ion exchange procedures are being studied.

g. Present Operation. The radiological sciences department has the responsibility for monitoring and control of radioactive wastes disposal at the Hanford Atomic Product Operation (40). Protective measures include the following:

(1) The activity of the reactor coolant is continuously monitored before being discharged into the Columbia River. The concentration of gross alpha and beta particle emitters and certain specific radioisotopes are monitored in supplementary samples of the water collected on either a daily or weekly basis at representative locations between the reactor areas and the McNary Dam. Special attention is given to the water supply of the towns of Pasco and Kennewick. From the McNary Dam to Portland, Oregon, a distance of approximately 193 river miles, samples are collected on a monthly basis.

(2) Mud samples are taken usually at the same time as the river water samples are collected. Thus far, no adverse effects have been observed on the ecology of the Columbia River.

(3) Livestock and crops are grown in the immediate vicinity of the Hanford Plant. Therefore, many samples of vegetation are analyzed for the extent and degree of concentration of radioisotopes. Approximately 70% of these samples are taken in the immediate vicinity and the remaining in remote sections in Washington and Oregon.

(4) Gas samples are collected directly from the stacks and discharge ducts. Continuous filter and scrubber samples are collected and analyzed.

(5) The radioactive concentration from air-borne materials and radioactive materials on the ground is determined at the perimeter of the production area near the residential areas surrounding the plant, and at remote monitoring stations throughout the Northwest.

(6) The concentrations of gross beta particle emitters is determined periodically in rainfall samples collected at random locations.

(7) Subsurface water samples are collected from monitoring and sanitary water wells in and around the project area. The radioactivity determinations are made on weekly or monthly bases, depending on the area and the use of the water.

(8) Within the plant, instrument surveys are performed at the perimeter of the open wastes area, and along the various ditches which discharge into retention areas.

Alpha and beta particle emitters in the Columbia River below Richland are considerably below 1/10 of the recommended maximum permissible concentration set forth by the National Bureau of Standards Handbook. Even more conservative maximum permissible concentrations are not exceeded in the sanitary well water supplies and in the air.

Scientific research and development are used in Hanford to advance the knowledge of the technical, economical, employee health, and public health aspects of radioactive wastes disposal. Considerable work is done on analytical techniques. Basic considerations in chemistry, physics, biology, and electronics are part of the work. Meteorolgy is an important science in the consideration of airborne radioactive gases and particles. Investigations of the ground, ground-water, surface water, and general geologic studies are fundamental to the disposal of radioactive wastes. The research and development investigations are conducted by highly qualified technical personnel. State and Federal Public Health officials are kept informed of the waste disposal and control programs through an advisory group. They,in turn, advise on matters of public health significance.

The Shippingport nuclear power plant (43) consists of a pressurized light water cooled and moderated heterogeneous thermal type reactor, employing a combination of highly enriched and natural uranium fuel assemblies. The plant has no facilities for processing the spent

fuel elements; these presumably will be shipped to one of the national laboratories equipped with fuel element processing facilities. Therefore, radioactive wastes to be disposed of at this site will include only those incident to the operation of the reactor itself and will not be of high concentration. The primary waste sources and quantities are as follows:

WASTES	FLOW gpm	RADIATION--Cps/cc (disintegrations/sec./cc.)
Misc. Liquid Waste	50-400	1×10^6
Primary Coolant Decontam.Sol. and Flush Water	50-75	5×10^6
Low level Lab. and Laundry Wastes	50	1.3
Cond. Cooling Water	68,000 minimum	----

The activities in the ion exchange resin from the purification system and in the decontamination fluids and primary system effluent are too high to permit dumping into the river. The volumes involved are too great to make packaging and subsequent disposal at sea feasible. The waste disposal system will consist of two stage evaporation to reduce bulk, and subsequent underground storage of high activity evaporation bottoms at the site. Spent resins from the demineralizers will be flushed directly into underground storage. Provision for collection and storage of radioactive gases is being made. Dilution and discharge through a vent stack will be used when meteorological conditions permit. The evaporator feed will be from 9,000 to 21,000 cu.ft. per month, depending primarily upon the decontamination procedure. Evaporator vapor will be condensed and diluted with condenser cooling water before being released to the river. Permissible activity released to the river is being taken at 10% of the standard tolerance. A study is underway to determine the most economical method of disposing of combustible radioactive wastes. The methods being considered are: incineration at the site, or baling and shipping for disposal at sea. High and low activity laboratory wastes will be segregated at the source and processed through the evaporator or diluted as dictated by the activity.

h. Cost. For a reactor burn-up of 5,000 megawatt days in heat per ton, the processing volume is 1200 gal/ton, and the allocated cost for waste disposal is 2%, or 0.16 mills/kilowatt hr. (35). Then the allowable cost of waste disposal was estimated to be $4/gal.

At Hanford, non-boiling wastes in 500,000 to 1,000,000 gallon tanks can be stored in reinforced concrete tanks with mild steel liners, at a cost of 20 to 25 cents/gal. (31). Self-concentrating wastes may be stored at a cost of 40 to 50 cents/gal tank space. This cost amounts to only 0.01 to 0.05 mills/kilowatt of electrical power produced.

Therefore, it presents no particular economic problem.

With a basic life of 3 years, it is estimated (35) that the cost of ground disposal amounts to 0.1 cents/original gal. The cost of operating burial sites range from \$1.52 to \$9.40/cu.yd. of material, not including sample containers, processing, and handling (35).

Costs of disposal in the Irish Sea at Seascale, England (35) including packing and handling at sea varied from a low of \$.30/lb. along the east coast to \$.80 to \$1.00/lb. along the west coast.

Experience was reported (35) of the demolition of an alpha contaminated building of 48,000 sq.ft. The cost of the demolition and burial was approximately 5 times greater than that of demolishing a normal building.

After 3 months of operation of the Shippingport Pressurized Water Reactor, it was reported (21) that the overall cost of the plant was \$121.4 million. The cost of the power produced is 64 mills/kilowatt hr. based on a 60,000 kilowatt output. However, this cost should drop, for the plant will ultimately run at a net power level much greater than 60,000 kilowatts. For comparison, a large conventional fuel steam generator can produce a kilowatt-hr. for 5 to 10 mills.

i. Biological Effects. Studies in the Columbia River below the Hanford plant, (34) showed no significant change in the biological abundance downstream, but there was a marked decrease in the radioactivity in the organisms downstream for a distance of 60 to 100 miles. Young organisms contained more radioactivity than adults, and the principal isotope was phosphorous 32. Near the reactors, plankton had the highest activity, while farther downstream insect larvae and small fish were more radioactive. Relatively high radioactivity was found in white fish which had migrated from the reactor area upstream. A survey of a White Oak Creek near Oak Ridge, Tenn., showed some radioactivity in all of the biota, the most important radioisotopes being phosphorous 32, strontium 90, and cesium 137.

It was found (29) that radio-phosphorous, one of the waste constituents of the Hanford reactors in the Columbia River, was concentrated more than 100,000 times by certain small fish in the river, even though the radio-phosphorous in the Columbia River is reported to be well below dangerous levels. Thus, if radio-phosphorous were allowed to reach the maximum level permissible for drinking water, organisms living in the water could suffer radiation damage and the fish would be unsafe for human food.

j. Gaseous Wastes. Extensive experiments were carried out at Brook Haven National Laboratory, New York, to define air dispersion patterns. (35). The data showed that there was an orderly gradation of dispersion, which could be predicted from calculations of the data. Ground level concentrations could be estimated during normal and inversion

conditions. However, the gustiness classification needs considerable improvement. The most suitable method of field sampling includes a large number of accurate devices operated simultaneously.

From an atmospheric radioactivity survey it was concluded (34) that radon accumulates during periods of calm air and is dissipated by winds.

Glass fibre filters were reported (34) to be 99.99% effective in removing particulate matter in the range of 0.2 to 0.7 microns in diameter from waste gas at the Hanford plant.

k. Reuse of Effluent. Industrial water supply is a legitimate stream use that can be impaired by the discharge of excessive amounts of radioactive wastes (46). Examples are: industries whose process waters must be relatively free of radioactive contamination such as the food processing industry, the photographic film industry, and the atomic energy industry itself.

The use of contaminated river water for irrigation can produce a hazard of direct public health significance (39). Radio-iodine and radio-strontium can be concentrated by plants from contaminated soil.

There is a potential hazard to animals which may graze on plants irrigated with radioactive water, and also the consumers of milk products from these animals (27).

Water-borne sewage can be sterilized by gamma radiation without activating or leaving residual radiation in the treated liquids (23). It is possible that radioactive waste products can be used to sterilize water, sewage, and other liquids.

Infinite doses of radiation of the type emitted by nuclear reactor wastes will decompose paper pulp wastes (23). All inorganic elements would be oxidized to their highest oxidation states, and organic substances would be decomposed into gaseous products and charred residue. Since it is uneconomical to give these materials infinite doses of radiation, practical methods were investigated to approach the ideal using only moderate doses. Three factors were found to be of prime importance in the development of such practical means:

(1) When atomic radiation interacts with matter, the ultimate net effect is the destruction of the compound. This is undesirable in almost every use except treatment of waste streams.

(2) Shielding may be accomplished by surrounding the fission source with the solution being radiated. It was found that 6 feet of water reduces gamma radiation to about 1 millionth of its initial intensity. Thus, rather than absorbing the excess radiation in a shield, the waste itself would absorb the excess. The flow would be directed by

baffles so that the fluids move into the zone of more intense radiation before discharge.

(3) As a safety measure some large nuclear reactors will continue to be built in remote areas. This may place the reactors near lumbering areas and thus reduce shipping charges. Presently some projects are underway to investigate the effectiveness of treating sewage, domestic water supply, and lake pollution through radiation of these materials by fission waste products.

Another investigation (23) seeks to demonstrate the practicability of destroying non-filterable viruses from sewage before they get into the receiving stream. Efforts are being made to develop cheaper and less cumbersome sewage disposal plants and devise methods for reducing lake and stream pollution to afford safer swimming and recreational areas. A private engineering firm in San Diego is studying the feasibility of recovering water and commercial fertilizer from sewage by treating it with gamma rays.

1. Present Status of States. A survey was made (36) of the status of State governments in handling problems involving the treatment and disposal of radioactive wastes. This included 44 states, Alaska, and Hawaii. The attitudes of the states were summarized as follows:

(1) Twenty-two states are placing complete reliance, at least for the time being, on existing authority within their public health and pollution control laws.(25)

(2) Only 7 states have specific legislative authority. In 4, this was statutory, in 3 through regulation of existing authority.

(3) Fifteen states had measures being prepared for the legislature.

(4) Sixteen states apparently had no program or activity.

(5) Sixteen states reported minor activities such as background surveys, occasional consultations, and some work with the Atomic Energy Commission on inspection of radioisotopes and participation in national air sampling network.

(6) Twelve states reported fairly extensive programs, including elaborate stream surveys, participation in site selections for nuclear energy plants, inspection and registrations of users of radiation, etc.

Most of the states depended upon the health and safety regulations of the AEC, or the recommendations of the National Committee on Radiation Protection, National Bureau of Standards. This is in contrast to the states' normal variation in policies for pollution control. The replies indicated that extensive use is being made of consultation services from the AEC, and their contact, the U.S. Public Health Service,

and the universities and colleges. A few indicated representation on committees, with these agencies reporting this to be an excellent method for exchange of views. Thirty-three states have availed themselves to the various training opportunities, especially those conducted by the U.S. Public Health Service. Seven states had an all-out effort including graduate training for key personnel, and short course training for all other persons having any connections with the program, including persons from local health authorities. Three states had adequately equipped laboratories for a complete program, and another seven had minimum facilities. Ten other states reported a definite intention to provide laboratory facilities soon. Seventeen states reported having personnel actually assigned specific responsibility, but in most cases this was minimum, consisting of one or two part-time persons. Twelve states indicated that regular employees handled the work as needed. Many specific problems were noted, including radiation hazards from military or other classified installations, desire to set background levels, anticipation of extensive development of power reactors and related process facilities, concern in the use of radioactive tracers, and many others. It appears that very few cities have taken any steps toward the control of radioactive discharges to sewer systems. Five large cities are reported to have control through provisions in their sewer use ordinances and have established monitoring programs.

A cooperative effort between the states and the industries involved is recommended. The states are short on competence to handle the technical complexities and the public does not favor the prospect of industry evaluating its own problems and policing itself. For the team approached to work productively, industry must recognize the jurisdiction and responsibility of the states and the states must be as practical and reasonable as the situation will possibly allow. Such team work was practiced at the Hanford, Washington installation. The Columbia River Advisory Group now meets bi-annually for one or two-day sessions.

In the Atomic Energy Pact of 1954, a sincere effort to consult with the states on matters of radiation protection has been made and a program has been initiated which will ultimately provide the basis for a harmonious Federal-State relationship in the field of radiological health.

In developing state legislation, it appears extremely important to have uniform laws, at least on the technical phases of the problem. Therefore, it is important to establish:

(1) What constitutes a good uniform law on the subject under certain circumstances, and (2) how far should state statutes go to control the situation which is presently in the hands of the Federal government. The training of personnel for activity in the field of atomic energy is a prerequisite for a sound program in the field of radioactive wastes disposal. In this area the need is for:

(1) A coordination of training at the Federal level, (2) The recruitment of qualified personnel by pollution control agencies, (3) Sound financial support for training programs, (4) Opportunity to gain realistic experience in the program. It is generally recognized that any successful program must have adequate financial support. Unfortunately, necessary expenses in this field are very high.

There are many problems involved in setting up a state program. However, if the states intensify their efforts, developing this program immediately, there is good reason for the belief that the attitude and cooperative hand of industry in the control program of the AEC will allow the states sufficient time to attain competence and resources. Generally, the public is on the side of the pollution control authorities. In extremes this may be a disadvantage. This should aid in the establishment of a good state program. In addition, a wide variety of training opportunities is available. Unless proper precautions are exercised now, succeeding generations, even those that live 5,000 years in the future, may suffer from defects which they may trace to us. States must take their share of the load. They must use all the technical information and experience at their command to make a careful evaluation of each problem so that its impact from both present and future generations can be determined. The states must also consider their readiness and their resources available which will enable them to arrive at reasonable and practicable solutions to problems of radioactive wastes disposal.

The United States is on the threshold of practical electric power production from atomic energy. The growth of the atomic energy industry depends upon satisfactory waste disposal methods (45). It has been predicted that 90,000,000 gallons of highly radioactive fission product wastes would be produced daily in processing nuclear fuel from power reactors built during 1964 alone. The permissible limits of radioactive material in water are very low, and the different radioactive constituents have individual response characteristics to treatment processes.

The problems of control and treatment of radioactive wastes are many and complex. Solutions to these problems can be found if efforts are made by appropriate agencies. These efforts must be made as soon as possible in order that progress in this Atomic Age may proceed unhindered.

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SECTION XIX

WATER QUALITY IN THE LOWER DELAWARE RIVER WITH SPECIAL EMPHASIS UPON POLLUTIONAL ASPECTS

19-01. GENERAL INTRODUCTION

In view of the complexity of pollution movement and stabilization in an estuary, it is deemed appropriate that a separate section be devoted specifically to this aspect. The dissertations to follow are of a summary nature with general conclusions and have been prepared in a condensed form primarily for expediency and ease of reading.

The State of Delaware has conducted water quality (pollutional) investigations in the Delaware River since 1952 (5). Considerable time, effort, and money have been expended in the last 3 years to study not only the prototype, but also the Delaware River Model at the Waterways Experiment Station at Vicksburg, Mississippi. Much of the study work in this 3-year period has been conducted jointly with Incodel. The conclusions and comments contained in this section, drawn from the intensive investigative phases, are those of Delaware. However, a detailed formal report will be prepared jointly with Incodel in the near future. Due to the volume and complexity of data collected, the formal report phase will require from one to two years for its preparation. Throughout this section reference will be made to the data collected during the more recent 3-year period.

During the past 7 years an extensive survey of the literature covering the various aspects of stream pollution has been conducted with special emphasis upon the problems related to the tidal area of a stream, or the estuary. This survey of literature covered not only material contained in technical publications, reports, and private investigations, but also reviewed the newer phase of research employing continuous discharge techniques on the Delaware River Model.

When dealing with an estuary one cannot emphasize too strongly that such a body of water has certain inherent complexities which are not present in streams unaffected by tidal action. Employing the old concept that "dilution is the solution to pollution" would lead to many erroneous conclusions. Due to the nature of water movement in an estuary, certain conditions are created in regard to pollution buildup and recovery which need special considerations. Some of the more important observations are briefly summarized as follows:

a. An estuary receiving pollution in the form of a continuous discharge will result in a concentration buildup far exceeding that which can be anticipated from the uniform dispersion of the total daily loadings.

b. An estuary such as the Delaware River is, in essence, in a state of equilibrium and presently any daily loading is only a small portion of the existing accumulated concentration within the stream at any time.

c. Some of the more important factors of flow, transit time, temperature, and dispersion have variable effects in different portions of the estuary. For example, the effect of increased flow upon water quality is not the same in the upper reach of the estuary as compared to the lower reach.

d. The pattern of runoff and the total volume involved are extremely important with regard to pollution buildup and recovery.

e. Sediment problems will always be present, either through direct solids discharge, erosion, or chemical coagulation and/or flocculation of industrial-type wastes. Regimentation of the natural runoff pattern will reduce the effect of scour.

f. The total volume of water within the drainage basin area is extremely important, in that each gallon of water carries dissolved oxygen and has a definite recovery ability. Any decrease in volume will lessen the total recovery capability. Benefits derived from controlled flow and/or diversion must be carefully weighed against the disadvantages in specific areas with regard to pollution abatement.

g. Transit time, which represents the average movement time of a contaminant, is of comparatively long duration, pollution-wise, which, in turn, makes the Delaware River a large waste recovery system. Present loadings, represented in the form of pollution buildup, and any future additions, will be contained and stabilized within the Delaware River estuary. The recovery capacity of this drainage basin system will dictate the limit of present and future loadings, since wastes are not carried to the sea but are stabilized by nature before reaching the Bay itself.

h. Due to the long transit time inherent in the Delaware River estuary, controlled and/or augmented flow in the upper basin will result in a change of the pollution regimen and of salinity movement. Any short-term estimate to determine the maximum concentration buildup of either pollution or salinity can result in extremely low values. A continuous and gradual buildup of both pollution and salinity will take place over an extended period of time until equilibrium is reached. This maximum will be affected not only by the rate of discharge but also by the total volume passing down the estuary over an extended period of time.

19-02. CHARACTERISTICS OF THE DELAWARE RIVER ESTUARY

a. Introduction. In the above general introduction, various observations were made which were taken from the works of other investigators and from the experience and knowledge of the Delaware Water Pollution Commission. The problem is to relate these general observations

quantitatively to the Delaware River Basin. It is imperative to know the pollutional load reaching the river, the present water quality, and the sources of pollution. These findings lead to the following all-important questions:

(1) What is the present recovery capacity?
(2) What is the effect of controlled and/or augmented flow?
(3) What would be the effect of diversion of waters out of the Delaware River Basin upon the existing and future quality in the lower estuary?

The following sections will contain, in a summary manner, the results from the numerous investigations made in order to provide answers to the above questions. Some of the data fulfill the needs rather completely and some will require further investigation. However, a major step forward has been taken toward establishing the recovery capacity of the Delaware River and the effect of flow upon its water quality.

The various differences between estuarine waters and those of "straight-run" streams are discussed in detail elsewhere (6, 7); hence these phases will not be repeated herein. Specific reference to water quality conditions in areas upstream from the Delaware-Pennsylvania State line will not be contained in this report. The details in this regard will be forthcoming in a joint publication with Incodel. Specific quality conditions in the extreme lower portion of the estuary, within the jurisdiction of the State of Delaware, will, however, be referred to occasionally below. In order to explain more fully the general patterns of movement and/or contaminant dispersion in the estuary, reference is made to certain investigations which cover the entire tidal area, namely, from the Delaware Bay to Trenton, New Jersey. These latter results show primarily the relationship between high- and low-water slack conditions.

b. Methods of Measurement. The river sampling technique used followed the procedure set forth in the Water Pollution Commission's Delaware River Report, Parts I and II (6). All analytical measurements were performed in accordance with Standard Methods for the Examination of Water, Sewage, and Industrial Wastes (8).

Many series of investigations or experiments were performed in 1957 and 1958 wherein samples were collected under high- and low-water slack conditions from the Bay to Trenton, New Jersey. Various analyses were made on each of the study series and the results are being compiled in detail for the formal report referred to previously. Some of the more pertinent findings are contained herein since they present a reasonably good account of what takes place in the river under various conditions.

c. Salinity Movement. The range of salinity within the estuary is of importance to the shellfish, industrial, and ground-water interests. In Figure 1 salinity, expressed as chloride content, is compared during high- and low-water slack on September 15, 1958. The salinity front moves uniformly upstream under high-water conditions.

d. Dissolved Oxygen Relationship. The dissolved oxygen content is one of the more important parameters for measurement of pollution. It constitutes a composite evaluation of the effect of organic and, at times, inorganic pollution. Such discharges will decrease the dissolved oxygen content of a stream and affect various important water usages. In Figure 2, a comparison of the dissolved oxygen content during high- and low-water slack is illustrated. It is clearly evident that the Delaware estuary is not too different from other estuaries receiving waste loadings, in that there is a depression of quality in the more developed urban and industrial areas adjacent to the stream. It is important to note that the upper stream areas have a higher dissolved oxygen content during low-water conditions, whereas downstream areas experience less oxygen. During high-water slack conditions the reverse condition prevails. The critical point, or the lowest quality area, moves upstream and downstream with the tidal movement. However, the concentrations do not change markedly in certain critical areas from high- to low-water. This phenomenon is typical of most estuaries

e. Color. Color is another parameter used in pollution evaluation. In Figure 3, a comparison is made of the color content during high- and low-water slack on September 15, 1958. Here again, it is evident that the peaks and depressions do not actually rise and fall; they merely shift up- and downstream with the tide.

f. Turbidity. Turbidity is also used in pollution analysis and indicates not only direct suspended solids discharges, but also generally shows conditions in the river with regard to bottom sediments and other activities. Again, it is evident that when comparing turbidity content levels during high- and low-water slack, as shown in Figure 4, that the normal shift upstream and/or downstream takes place depending upon tidal direction. However, the various maximum and minimum values do not change materially.

g. Reaction pH. The reaction pH is a measure often used to express the approximate buffer capacity of the system. This analysis is not overly sensitive to the effect of acid or alkaline-type wastes in such a large system. However, as shown in Figure 5, the variations of pH during high-water and low-water slack indicate that certain acid conditions do occur in the Delaware portion of the estuary. The more important observation here is to note that this particular analysis shows the normal shift with the movement of tide as was evident in the other analyses.

h. Nitrogen Balance. In the mechanism of decomposition of waste material, more commonly referred to in streams as stabilization, certain proteinaceous materials, among others, will in time decompose into various intermediate compounds, one of which is ammonia. Ammonia, in turn, reacts with the oxygen in the stream to produce nitrites and the nitrates. This latter compound is the final stable form which, as a rule, is a good indication of stable river conditions. During this process of reaching the nitrate form, the oxygen in the stream, if loadings are sufficiently heavy, may become depleted to a point which may have serious effects on other

water uses. Consequently, the measurement of ammonia, nitrite, and nitrate becomes an important part of any pollution investigation. The relationship, called the nitrogen balance, of each of these compounds to each other helps indicate the existing degree of stabilization. Figures 6, 7, and 8 show the comparison of ammonia-nitrogen, nitrite-nitrogen, and nitrate-nitrogen, respectively, during periods of high- and low-water slack. Again, it is rather evident that there is a shift in the maximum and minimum concentrations with the change of tide. This pattern is similar to those observed in other analyses. The nitrogen balance shown in Figure 9, however, depicts the typical relationship during low-water slack in which the ammonia is at first more pronounced (fresh pollution) until it is oxidized, or reacts with dissolved oxygen in the system, to produce nitrite which forms a secondary peak and then the nitrate follows similarly. A typical example of the nitrogen balance during high-water slack, measured on June 10, 1957, is shown in Figure 10. The progressive relationship of the various nitrogen constituents is well expressed in this presentation.

A full and complete story of all the nitrogen compounds contained in the river is not complete unless total organic nitrogen is included. These nitrogen compounds are not measured by the ammonia, nitrite, or the nitrate analyses. A true picture of the total nitrogen buildup in the river as we move downstream is shown in Figure 11 and presents a comparison during high- and low-water conditions. The shift, again, is quite evident. Expressing total nitrogen in pounds, in order to remove the masking effect of dilution, a continuous and accumulative type of buildup occurs in the river. This accumulative phenomenon, which is characteristic of the total nitrogen balance, is very significant since it presents a direct measure or indication of nitrogenous type pollution in the estuary as we proceed downstream. The individual nitrogen compounds may vary in concentration; however, the total weight of nitrogen remains essentially the same. Consequently, any increase in total nitrogen that may be observed can be directly attributed to additional pollutional loadings.

i. Summary Observations. The above series of figures were included to give the reader a better understanding of pollution movement in the river as measured by various pollution indicators and their relationship to tidal conditions. It is evident from the typical examples that water quality does not materially change between high- and low-water slack, and the only noteworthy change that takes place is a shift up- or downstream. This fact emphasizes the importance of clearly defining the effect of pollution or the buildup of pollution as related to flow with respect to location and tidal conditions.

19-03. CHARACTERISTICS OF THE DELAWARE RIVER ESTUARY WITHIN THE STATE OF DELAWARE

a. Introduction. Many studies with regard to waste movement and recovery capacity in estuaries have been carried out by numerous investigators, specifically the British (4). Most researchers, however, have used their data, or data from other studies, to develop a theoretical method for finding the recovery capacity applicable to all estuaries.

A search of the literature will show the various methods or techniques. These theories, when applied to the Delaware River, were either non-applicable or not complete enough to justify the use of a specific procedure. Some of the methods required use of extensive additional data in order to obtain a statistically valid evaluation. It was evident that not only are complete pollutional loading inventory and existing water quality information needed, but also the flow characteristics, contaminant dispersion, and the configuration of the specific estuary are of vital importance to any solution.

Since the Corps of Engineers Water Resources Survey was scheduled for completion in 1959, the time available to make a valid pollutional study of the Delaware estuary became a critical issue. The question arose early in 1956 whether a more practical or less theoretical method of measuring recovery capacity could be devised which would apply to the Delaware River and, coincidentally, to estuaries having similar characteristics. Two significant facts were known which indicated a "short cut" solution was within the realm of possibility. The 1952 studies (5) of the Delaware Water Pollution Commission showed that in excess of 90% of the total pollutional load existing in the estuary was confined in waters 20 ft. or more in depth. Secondly, these same studies and those conducted by the Waterways Experiment Station on the Delaware River Model (3) showed complete vertical mixing since this estuary is a comparatively shallow body of water. These two characteristics inherent to the Delaware estuary decrease or obviate the otherwise necessary study with regard to littoral areas and stratification. Further, the availability of the Delaware River Model for theoretical dispersion studies would prove invaluable with respect to saving time.

As indicated previously, it is basic for the present study to know the waste recovery capacity of the Delaware, but in view of the anticipated flood control measures through upstream impoundments, the effect of flow on pollution abatement problems also becomes an important issue.

Most of the analyses for pollution made in estuaries prior to 1956, both in Delaware and elsewhere, were made not only under different weather conditions and flow but also at various stages of the tide. It is fundamental in evaluating data from any estuary that in order to determine the effect of any single factor, either sufficient detail must be known of all the variables involved, or the conditions must be such that each variable can be considered singly. It is known that temperature, flow, weather conditions, stage of tide, and river configuration are extremely important to pollution study evaluations. Consequently, in order to estimate the effect of flow even qualitatively, the influence of the other variables referred to above must be kept at a minimum. In order to reduce the variables as much as possible, extensive analyses were made on samples collected during either high- or low-water slack in accordance with procedures established in the 1956 studies (6). This "same-slack" procedure provided the means of collecting samples under similar weather conditions, flow, and temperature during a single period of slack. Variable weather conditions, which may affect results from location to location on successive days or

periods of sampling, were omitted since all samples for a single series could be collected during the same stage of tide by employing a sufficiently fast boat with special sampling equipment. During the summer and fall season of 1957 and 1958, in excess of 10,000 individual analyses were made during high- and low-water slack periods on the Delaware River estuary.

b. Method of Data Evaluation. In the following commentary, comparisons of data are made with the understanding that only the 20 ft. and deeper portion of the river, herein referred to as the effective volume, is under consideration only. Since this effective volume contains in excess of 90% of the existing pollution at a cross section, it is assumed that conclusions drawn on the basis of this magnitude would be valid for the river as a whole. In Figure 12 a comparison of total cross-section volume is made with effective volume measured during mean low water. The similarity is evident. If the higher velocities existing in the deeper portions of the river are considered, the percent of the total volume of water carried in the river by the effective volume would even be greater than shown in Figure 12.

Valid comparisons could be made of the findings if these analyses were grouped so that a minor temperature differential of only 1° C. existed within any single group of comparisons. Of the 21 complete series collected, 15 were done during low water slack. These 15 series, containing approximately 500 analyses each, were arrangedin 5 separate temperature groups accordingly. Consequently, comparisons are made within a temperature group and conclusions drawn. Then conclusions for each group are compared before drawing a single summary type conclusion.

Before the effect of flow evaluation could be made, the problem arose of assigning a flow figure or number to a series collected on a specific day. It was clearly evident that the daily flow reported at Trenton could not be used for comparative purposes simply because of the long time of transit within the river and the inherent characteristic of this estuary of being in a state of equilibrium. Specifically, an extensive period of steady flow is required before the river reflects the effect of this flow stage An examination of the flow data, as recorded at Trenton, indicated that a weekly average was not representative of the fresh water to salt water ratio present in the river. Further, on occasion even a 2-week average was not representative. In fact, in one instance a 3-week average was necessary within a temperature group to establish the true salt water ratio that existed within the estuary Consequently, each temperature group was separately considered for consecutive average weekly flow periods until a stationary relationship existed which was comparable to the existing salt to fresh water ratio Within each temperature group the final salt to fresh water ratio was assigned a chloride number (1 to 4), each increasing number corresponding to an increased flow stage The chloride number assigned within a given temperature group does not represent the same flow in a subsequent temperature group even though it has the same

number. These chloride numbers are used for comparative purposes within a single temperature group only. In this way a true comparison of the effect of flow at constant temperature within any group could be made.

c Flow Relationship Expressed as Chloride Number. Examples of the comparative chloride number, or the salt to fresh water ratio, for the lower Delaware River between the Delaware State line, commonly referred to as Marcus Hook and areas downstream, are shown in Figures 13, 14, 15, 16, and 17. These five temperature groups, as explained above, agree with the average weekly flow at Trenton for periods of one, two, or three weeks or coincidentally, with an occasional daily average, depending upon the conditions existing at the time It is evident from these presentations that during periods of similar flow stage, the curve patterns are almost congruent, and where flow stages are markedly different the deviation between the curves is increased. In Figure 17 special reference is made to chloride number 2 dated June 4, 1957. The downstream portion of this curve shows a sharper rise than was evident in the other three examples. This condition was created by a period of increased precipitation which occurred approximately 10 days prior to this period of sampling, and it is evident from the downstream portion below New Castle that the effect of this increased precipitation still persisted. This type of runoff, which is conducive to increased scour, will crop up occasionally in the discussion of the presentations to follow, particularly within this temperature group series.

d. Dissolved Oxygen. In previous sections it was pointed out that comparing individual constituents within the effective volume on the basis of loading in pounds would eliminate the effect of dilution and would be the most valid means of comparison. The effect of flow upon the dissolved oxygen content, to be discussed below, is reported on this basis. In Figure 18, the dissolved oxygen content on October 10, 1957, is compared to that of October 16 of the same year. Even though these two periods represent only slightly different flow stages, it is clearly evident that during periods of increased flow the State of Delaware experiences a decrease in dissolved oxygen. In Figure 19, a comparison is made of the data collected on August 15, 1957, with that collected on August 19, 1958. Again, it is evident that during periods of increased flow the State of Delaware experiences decreased dissolved oxygen levels. A similar conclusion can be drawn from the group series shown in Figure 20 where the results from August 29, 1957, September 3, 1958, and July 1, 1958, are compared. In these first three-group comparisons, the flow stages were not only progressively increasing, but also each curve in any of the three temperature groups represents sufficiently divergent flow to illustrate sharp contrasts. In Figure 21, the curves represent a temperature group in which the flow stages are quite similar and at a comparatively higher level. It may be noted here that a reversal is taking place at increased flows. This reversal effect is more pronounced in the temperature series shown in Figure 22. The series taken on September 15, 1958, is at a considerably lower flow stage than those taken on June 19, 1958, June 24, 1958, and June 4, 1957. The reversal tendency is evident, in that the results show a movement in the direction of increasing dissolved oxygen content with increasing flow. It should be noted, however, none of these increasing flow series returned to the highest dissolved oxygen level content shown in

chloride number 1 even though they represent at least three times the flow of the latter. It was mentioned previously that the June 4, 1957 series will show certain evidences of scour since it represented a series taken only 10 days after a period of sharp precipitation. The results clearly show a more marked depression than would normally be expected if this period of precipitation had not occurred. However, it does not alter the apparent trend, in that at greater than 5,000 cfs a reversal effect sets in producing increased dissolved oxygen levels in Delaware.

Therefore, within the State of Delaware (downstream from Marcus Hook) the following summary observations are clear-cut:

(1) During the low flow periods recorded in 1957 and 1958, the dissolved oxygen content was greater than the dissolved oxygen content measured during the higher flows.

(2) With progressively increased flow, up to approximately 5,000 cfs, there results an actual decrease in the dissolved oxygen content which is always less than the levels observed during the driest periods of low flow.

(3) With continued increasing flow, a reversal takes place, in that the dissolved oxygen content stops decreasing and begins increasing progressively; however, the level remains less than the original low-water content even with 10-day average flows as high as 7,100 cfs.

e. Biochemical Oxygen Demand. The biochemical oxygen demand (BOD) is one of the important parameters used to measure the residual pollution within a body of water, since it most nearly expresses the biological and chemical requirements in the form of oxygen demand needed to stabilize the existing pollution. Normally, a 5-day BOD is employed for expediency. However, in view of the long transit time involved in the Delaware River, ultimate long term BOD studies were performed in order to improve the validity of this analysis. The ultimate BOD correction factor was applied to all the data accordingly and recorded as pounds of ultimate BOD in the effective volume. Comparisons of these ultimate BOD values within the typical temperature group series are presented in Figures 23, 24, 25, 26, and 27. The general conclusion that increased flow will result in decreased quality is evident from these series of curves. However, the results do not in all cases present as clear-cut a picture as was evident from the dissolved oxygen comparisons. In Figure 23, a marked increase in BOD content occurred with increased flow if one compares the lowest and the highest flows occurring August 29, 1957 and July 1, 1958, respectively. However, in this series the September 3, 1958 BOD values do not show a marked increase over that of August 29, 1957. This relatively small increase may be explained, in part, by the fact that other evidence, such as a marked decrease in coliform content at the State line, indicated strong toxicity which may have affected the

subsequent ultimate BOD values. It is highly probable that if this strong toxicity did not exist, the September 3, 1958 series would have shown appreciably higher BOD values. In Figure 24, a comparison is made of the ultimate BOD contents on October 10, 1957 and October 16, 1957. This is the only series that shows a completely different story from the other figures in the BOD groups, in that higher ultimate BOD values were evident during the slightly lower flow period. In Figure 25, the results show again that with increased fresh water flow the ultimate BOD was higher. The effect of fresh water flow for the temperature group illustrated in Figure 26, in which the flow stages are rather similar, shows the highest ultimate BOD's to exist with the highest flows. In Figure 27, it is again evident that with increasing flows higher ultimate BOD values are present. In all cases the higher flows exhibited considerably higher BOD values than the low flow represented on September 15, 1958. It should be noted, however, that the scour type flow on June 4, 1957 exhibited an extra sharp peak, which is as expected.

In conclusion, it may be reasonably stated that all except one of the five temperature series showed a general pattern of increased BOD within the State of Delaware with increased flow. This confirms the conclusion already drawn from the dissolved oxygen series.

f. Buffer Capacity Relationship. The present level or load of acid-type waste entering the Delaware River downstream from Marcus Hook has not reached undesirable proportions; however, the presence of these acid wastes is evident from the alkalinity, acidity, and reaction pH measurements. Of these means of measuring the effect of acid waste on the buffer capacity of the stream, the alkalinity test is the most sensitive and the reaction pH the least. As a rule, the buffer capacity has its source from upstream sources, or, more clearly stated, greater alkalinity exists upstream from the State of Delaware due to the lack of large acid discharges. However, the lower stretch of the Delaware estuary within the State of Delaware is influenced by the high buffer capacity of the Bay waters which is evident in all alkalinity and acidity measurements. This latter phenomenon is clearly evident from the comparison of variations in alkalinity and acidity during low-water slack on September 15, 1958, as shown in Figure 28. The peak in acidity corresponds to the existing acid-type discharges in the river and the very high alkalinity seaward is attributed to the effect or influence of the more saline Bay waters. It is evident from Figure 29 that the effect of acid waste is reduced during periods of increased flow. It is also interesting to note in Figure 29 that the three curves represented by the chloride curve numbers 2, 3, and 4, which have quite similar flow stages, have also similar alkalinity concentrations. The effect of fresh water flow on alkalinity content illustrated in Figure 30 may at first glance be misleading. Initially, one may conclude that the lowest flow of August 29, 1957 shows a relatively high alkalinity. It may not be appropriate to compare this particular chloride curve with numbers 2 and 3 since it corresponds to a period of extremely low flow when the upstream movement of high buffer-capacity Bay waters occur It is clearly evident, however, from chloride numbers 2 and 3,

which were taken during this same year (and not directly influenced by the effect of temperature), a marked increase in alkalinity or buffer capacity occurs during periods of increased flow. The explanation provided for Figure 30 in a way applies to Figure 31. Since the August 15, 1957, curve series represents a long period of extremely low flow and buffer effects from the Bay waters are evident for great distances upstream, the higher than normal alkalinity content is expected. Again, the same phenomenon is present in Figure 32, in that if the extremely low flow period of July 15, 1957, is separately considered, it is evident from the chloride numbers 2 and 3 curves, represented respectively by the series taken on August 5, 1958 and July 8, 1958, that an increase in buffer capacity occurs with increased flow. In conclusion, the results show that during extremely low flow, good buffer capacity prevails due to sea water, but considering river water only, higher flows produce greater buffer capacity.

The effects of fresh water flow on acidity content measured during low-water slack are illustrated in Figure 33. These curves show a progressive increase in acidity with increasing flow, and again the chloride number 2, the June 4, 1957 series, shows a disproportionate increase due to the scour as explained previously.

Variations in pH with fresh water flows during low-water slack are shown in Figures 34 and 35. Here again, it is evident that the buffer capacity improves with increased flow primarily due to the excursion of higher alkaline water into Delaware during these periods of increased flow.

g. Color. Variations of color content with fresh water flow during low-water slack are illustrated in Figure 36 and show generally an increase in color content with increasing flows. Somewhat of a contradiction to the above observation is evident in Figure 37, which expresses the color content during another temperature period. In the latter, the lower flow of October 10, 1957, has generally similar color concentration downstream to Cherry Island, whereas from Cherry Island downstream it shows a higher color concentration than that observed on October 16, 1957.

h. Turbidity. The effect of fresh water flow on turbidity content during low-water slack is presented in Figure 38. Here again, it is clearly evident that with increased flow there is an increased turbidity. This may be, in part, due to higher flows producing additional scour which distribute settled solids more into the upper water layers and also convey such solids farther downstream.

i. Hardness. The effect of fresh water flow on hardness content is shown in two examples illustrated by Figures 39 and 40. These patterns are quite similar to that of chloride content shown in curves 13 through 17. This congruency is as expected since hardness downstream from Marcus Hook is strongly influenced by the hardness of saline waters.

j. Total Iron. The total iron content within the lower Delaware River is of importance since iron discharges are made in this portion of the river. Much of the iron is in the flocculent state, and consequently the patterns of movement are similar to those of turbidity. This similarity of movement is evident in Figure 41 which expresses the variations in total iron with fresh water flow during low-water slack. It may be noted that during the lower flow periods of September 15, 1958, the peak of iron content was at Cherry Island, whereas during periods of increased flow the peak occurred at Pea Patch Island and showed a progressive movement downstream with increasing flow.

k. Total Nitrogen. The total nitrogen contents in the effective volumes, compared on a basis of the temperature groups, are illustrated in Figures 42 to 46. Each of these groups tells a comparatively good story, in that the total nitrogen curve shifts downstream with increasing flow. This shifting is congruent with the previous conclusions that decreased water quality is evident in the earlier stages of increasing flow within the State of Delaware. The greater the differential of flow level, the greater this shift. This is as expected since the more marked depression areas existing above the Delaware-Pennsylvania State line move as a unit into the State of Delaware with the increased flow, and there is a corresponding shift in the total nitrogen content phase. For example, in Figure 42, when the difference in the flows is relatively small, as with the comparison of October 10, 1957 to October 16, 1957, the shift is present but comparatively small. In Figures 43 and 44, it can be seen that when the divergence of flow is greater, the shift is proportionally greater. In Figure 45, however, the shift pattern is still evident, but the relationship of high to low flow is not as marked and this, in part, is due to the fact that each of these curves represents similar flow stages. The effect of flow is again evident in Figure 46 with respect to total nitrogen, in that the shift is downstream with increasing flow. The exception to the rule is the one value on June 24, 1958. In general, it can be stated that the total nitrogen in the effective volume indicates clearly that there is a shift in the total nitrogen content from an upstream area to a downstream area as a unit during an increase of flow and, in all probability, accounts for the decreased quality experienced by the State of Delaware under these conditions of flow.

l. Coliform Content. During the last year of study work on the Delaware River, the dilution technique of measuring coliform was supplanted by more promising and more rapid procedure of membrane filter (MF) technique. Consequently, examples are presented comparing results from the dilution tube technique and those of the MF technique. In Figure 47 are illustrated the dilution tube technique results in which it is clearly evident that during increased flow periods on October 16, 1957, as compared to the lower flow stage exhibited on October 10, 1957, there was a shift in the coliform peak from Cherry Island downstream to New Castle. However, there was a notable decrease in the maximum value. This may be attributed to dilution downstream. Figure 48 illustrates the results with the MF. These results show lower values for comparison since they measure only the

E.coli group and not the total coliform content. It is also evident from Figure 48 that with increased flows higher coliform counts occur, indicating a carry of the coliform content from upstream to downstream locations. In Figure 49, it is evident that the very low coliform content at Marcus Hook is not a true representation of the coliform present. From the BOD findings and other analyses, it was indirectly implied that toxic conditions existed at this location within the river and probably resulted in a depression in the number of organisms accordingly. From Cherry Island on downstream the toxic effect has been diluted or dissipated and the total coliform is higher during periods of higher flow. An interesting story is evident from Figure 50, in which the E. coli concentrations are compared for August 5, 1958 and July 8, 1958. Although measurements at the State Line indicate a high coliform content during the higher flow period, there is a reversal at Cherry Island when higher counts are noted during the lower flow period. There is no explanation offered by this one station variation. However, it is noteworthy that the E. coli peak occurred downstream during increased flow periods, which corresponds to the general shift observation derived from other analyses.

m. Other Analyses. The various typical analyses referred to above do not constitute the entire series used during the pollution investigations. Other constituents, such as total iron, hardness, oil, phenol, chemical oxygen demand, coliform, hydrogen sulfide, acidity, alkalinity, and biochemical oxygen demand, were included.

n. Summary Observations. In summation, the series of curves representing extensive data collected over several years clearly imply that:

(1) During increased flow periods in the Delaware River, the water quality sag shifts from upstream areas downstream into the State of Delaware.

(2) This shift takes place with increasing flow stages, and decreasing water quality will progressively reach the State of Delaware until approximately 5,000 cfs is reached. At this low flow stage, a reversal takes place with continued increased flow and progressively improved water quality results.

(3) Measurements made on the prototype at a maximum flow of 7,100 cfs still did not produce quality in the State of Delaware equivalent to that found during the lowest flow period, even though it was rapidly approaching the stage of quality experienced during the lowest flow periods.

(4) Since Delaware will experience decreased water quality with increasing flow, induced by upstream impoundments, either increased waste treatment measures must be provided upstream from the State of Delaware, or augmented flows exceeding 8,000 cfs must be the minimum control.

(5) The statement made in (4) is qualified to the extent that benefit from scour is progressively less with increased control of the river flow.

(6) In order for the water quality not to drop below the present conditions evident within the State of Delaware during periods of dry weather flow, it would be necessary for the State of Delaware waste dischargers to provide further treatment in addition to the suggestions set forth in section (4) above.

(7) Under the presently suggested flow controls of 3,400 and 5,500 cfs, the State of Delaware would, of necessity, have to provide secondary treatment for a present primary treatment discharge load of 100,000 P.E.

19-04. SUMMARY DISCUSSION

The generally accepted concept that increased flow improves water quality is open to serious questions when considering pollutional aspects in estuarine waters. Recent findings establish the fact that the effect of increased flow is not the same in all portions of the tidal area. Further, it is no longer a matter of degree of improvement but rather whether it is beneficial or non-beneficial. Unfortunately, the State of Delaware will be subjected to decreased water quality during periods of increased flow.

The entire problem, however, cannot be so simply resolved. Increasing the river flow progressively reduces the water quality in Delaware until flow stages of approximately 4,500 to 5,000 cfs (measured at Trenton) are exceeded. Thereafter, true dilution begins to emphasize its presence and water quality begins to improve with further increases of flow. However, the water quality in Delaware does not return to its original dry weather level even with flows exceeding 7,000 cfs. Control of flow may conceivably aggravate the problem if regulated at too low a flow stage.

Another seldom discussed phenomenon altered by control of natural flow is scour. It appears logical that Mother Nature has provided a wide range of river flow for the express purpose of providing a wide range of scour needed to flush all degrees of sedimentation from her rivers and estuaries. There is little doubt that the removal of peak flows will result in a decrease of scour. Further, peak flows just able to produce scour upstream will be only partially effective downstream since velocities of flow are sharply curtailed accordingly. Consequently, controlled river flow will reduce scour disproportionately in that upstream areas may be only slightly affected, while the lower reach may suffer considerably. At the comparatively lower stages of controlled flow, undesirable sedimentation may still be scoured from upstream areas into Delaware, whereas the needed peak flow to scour or further carry upstream sediment through this lower reach may become nonexistent.

The entire problem may be resolved to a matter of balance. Certainly one cannot help but recognize such potential benefits of flood control, water supply, and recreation upstream through regulated flow practices. One may also recognize similar benefits made available to downstream areas. However, improper regulation could create a non-beneficial effect on the lower reach of the estuary, specifically through decreased water quality, while still being beneficial upstream.

It is obvious that the needs for growth and development and their by-product, waste, are responsible for the dilemma we face. Naturally, these phases will continue to increase and our problems will become even more critical. Presently, the Delaware estuary receives a waste load from population and industry equivalent to approximately 4,200,000 persons after treatment. Of this total, Delaware claims the equivalent of slightly under 600,000 persons. It should be emphasized that this 4,200,000 load is after treatment, and the accepted degree of treatment was established indirectly by the ability of the Delaware River to consume the load without ill effect. Naturally, the potential total untreated load would be considerably greater, probably in excess of 10,500,000 equivalents.

Sedimentation of pollutional material in the Delaware estuary should be at a minimum since settleable solids discharges are not permitted and this requirement is complied with, for all practical considerations. Sedimentation will continue, however, due to soil erosion and interaction of colloidal and dissolved wastes with each other and/or salt water. These latter type discharges reaching the Delaware, after treatment, constitute the more difficult and costly portion of the waste to remove if and when the need arises.

Presently it is estimated that approximately 60% of the total waste load tributary to the Delaware Estuary is removed by existing waste treatment facilities. This 60% represents the average removal resulting from the existing primary and secondary units.

The primary degree of treatment (35% removal) is required of wastes tributary to the Delaware River from the State of Delaware. Complete treatment of a municipal waste containing a moderate amount of industry can be expected to remove 90% of the total load. Industrial wastes alone are not, as a rule, amenable to such a high degree of treatment simply because either technology is lacking or costs for a high degree of treatment become prohibitive. Since the industrial and domestic loadings in the Valley are essentially equal, the maximum degree of treatment may reach an estimated 80% reduction of the total potential load.

With a total load in the Valley of approximately 1,750,000 pounds of BOD per day, the existing 60% reduction results in 700,000 pounds reaching the Delaware daily. It has been estimated that the average increase of population and industrial development in the

basin will be 250% by the year 2010. Assuming the increase to take place uniformly, 100% increase can be expected by 1980. This would mean a pollutional loading of 3,500,000 pounds of BOD per day, and at the existing 60% removal would result in a river load of 1,400,000 pounds per day, or double the present discharge. At the contemplated maximum 80% reduction, a discharge of 700,000 in the year 1980 would occur, which is equal to the present discharge. Therefore, long before 2010 conditions would become untenable, in that the estuary would become an open sewer.

A fundamental part of the problem revolves about the present quality within the estuary and whether it is considered satisfactory for the best water usages. It has been pointed out previously that the State of Delaware will not require additional treatment at present since under normal conditions the water quality is satisfactory. However, following periods of increased flow during the summer and early fall seasons, Delaware experiences undesirable quality partly due to scour and partly due to the shift of the pollution sag from upstream downstream. Consequently, in order to maintain proper water quality in Delaware during the above seasons, either increased treatment must be provided upstream; increased treatment must be provided within Delaware as a partial measure; or augmented (increase of flow) flow must be prevented. It is inconceivable that, after complete treatment is provided upstream, the critical portion of the sag would have dissolved oxygen levels, one of the many pollution parameters, exceeding 2 ppm during periods of low flow. If presently projected controlled flows between 3,400 and 5,500 cfs are maintained, one can expect this sag of lesser quality to shift into Delaware. Will upstream sources undertake to provide complete treatment throughout Zone III (Incodel) immediately in order to maintain the present quality within Delaware before flow control measures are instituted? Under such conditions Delaware would not need secondary treatment before 1980. Lack of immediate action upstream would conceivably throw Delaware into secondary treatment long before 1980.

It is important to estimate the approximate cost of secondary treatment to Delaware. Thoman and Jenkins (9) published a method for projecting such an estimate from the Construction Cost Index and past waste plant costs. It is possible to predict the cost of secondary treatment; however, the method does not include additional operational outlay nor an Estimate Basis for populations exceeding 100,000 persons. However, employing this procedure for industrial as well as municipal needs would produce conservative values, since unit costs for industrial wastes are invariably greater. Using the population equivalent involved, some interesting cost data arise even though the values are on the low side.

A daily load of 100,000 pounds of BOD is discharged into the estuary from Delaware. On the basis of primary treatment, this constitutes an equivalent population load of 1,500,000 persons before treatment. In accordance with the method of Thoman and Jenkins (9) and the most recent Construction Index (1), the increased cost for

secondary treatment equals $950,000 per 100,000 population. Consequently, the cost would total $14,400,000, conservatively, for the addition of secondary treatment in Delaware.

Therefore, with the advent of stream regulation, the State of Delaware can expect lesser quality if the controlled flow is maintained at too low a stage during the summer and early fall, and a decrease in the scour of sediments. Lack of early consideration of treatment needs may require an outlay of funds for secondary treatment, compounded with cost of operation, exceeding $15,000,000 long before present projections. Unless other concrete benefits from low-flow augmentation can be shown for the State of Delaware, there exists considerable doubt of the good such an undertaking would achieve.

It appears evident from the above discussions that if secondary treatment of all wastes is completed, we shall, by the year 1980, be confronted with the artificial and natural recovery capacity limit for wastes tributary to the Delaware River. Due to practical and financial problems involved, it appears realistic to assume this limit may be reached even before the year 1980, since much must be done now to meet this minimum need. Being confronted with this period of criticality emphasizes certain statements made by various participants at the Barrier Hearing held in Wilmington on October 20, 1958. Much stress was placed by our neighbors on the aggravation of the pollution problems if a salt water barrier should become a reality. We reiterate our previous statement that the gravity of the waste removal phase is ever present in the not-too-distant future whether or not a barrier is constructed. The solution of the overall waste problem must, of necessity, take a new approach. The innovation could conceivably adopt the approach of segregating the more difficult wastes to treat and convey them through trunk sewers to the ocean. This procedure is essentially the procedure suggested in the San Francisco Barrier Study (2). Now is the time to resolve the waste disposal problems of the near future, not 1980 or thereafter.

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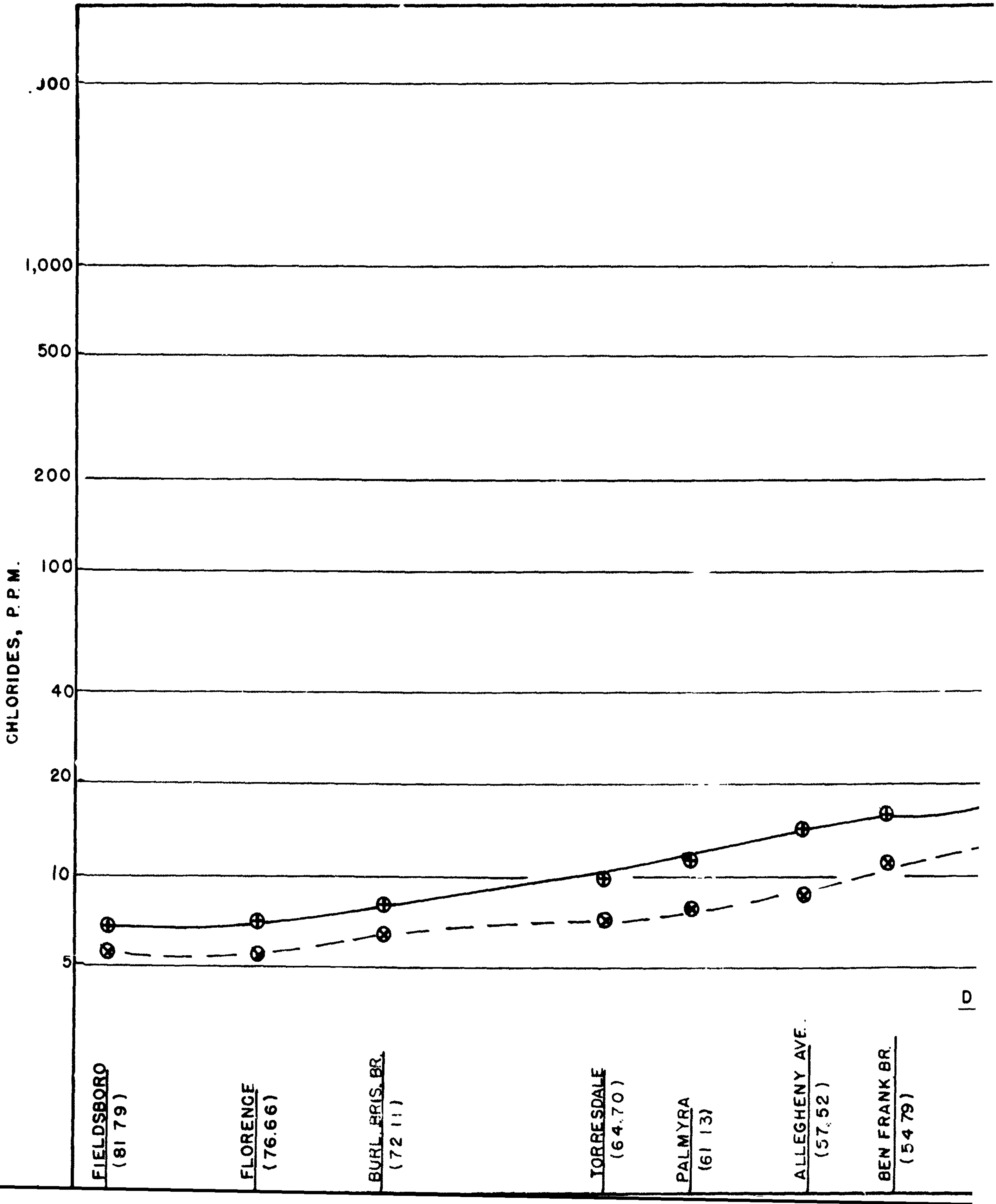
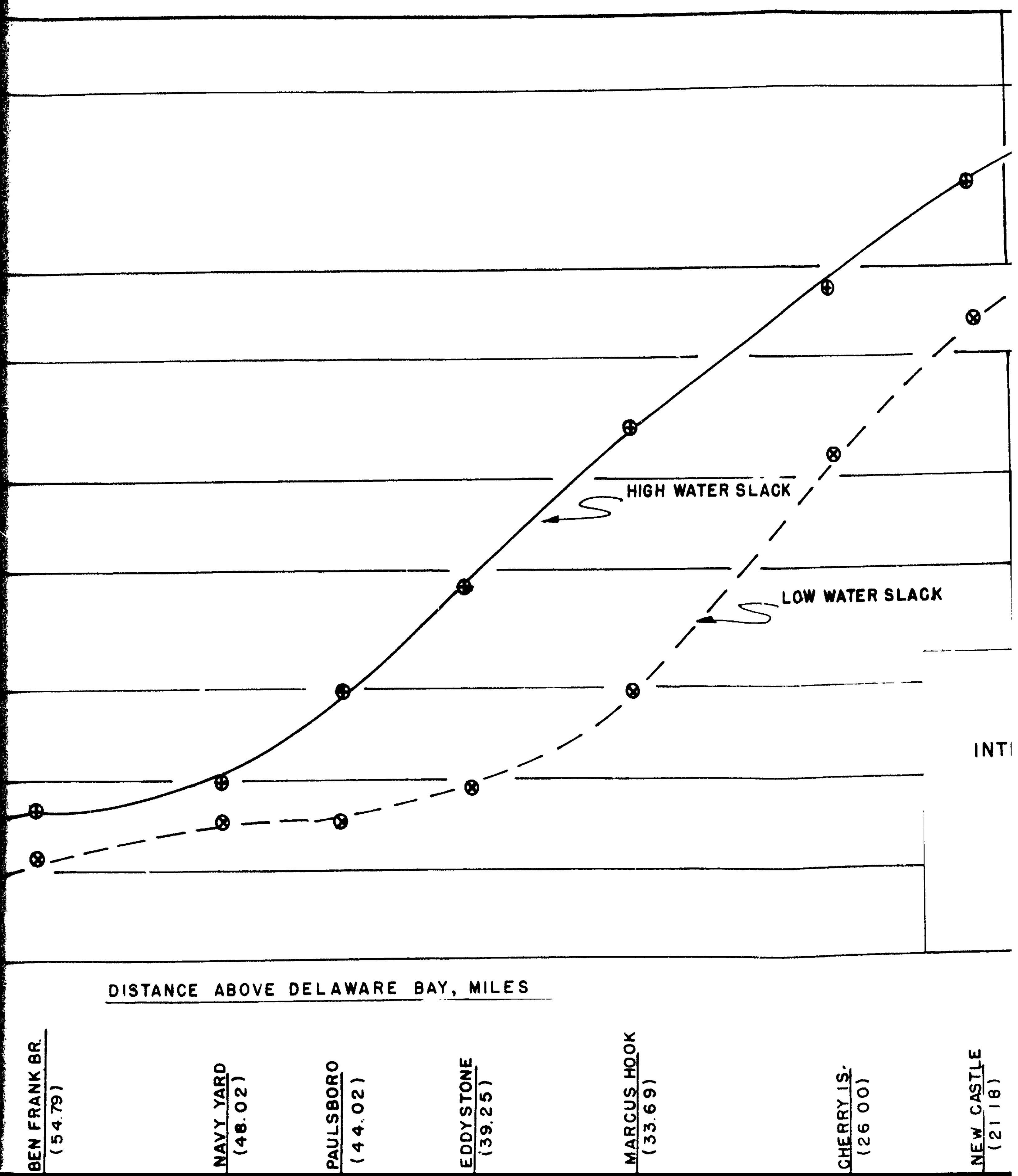
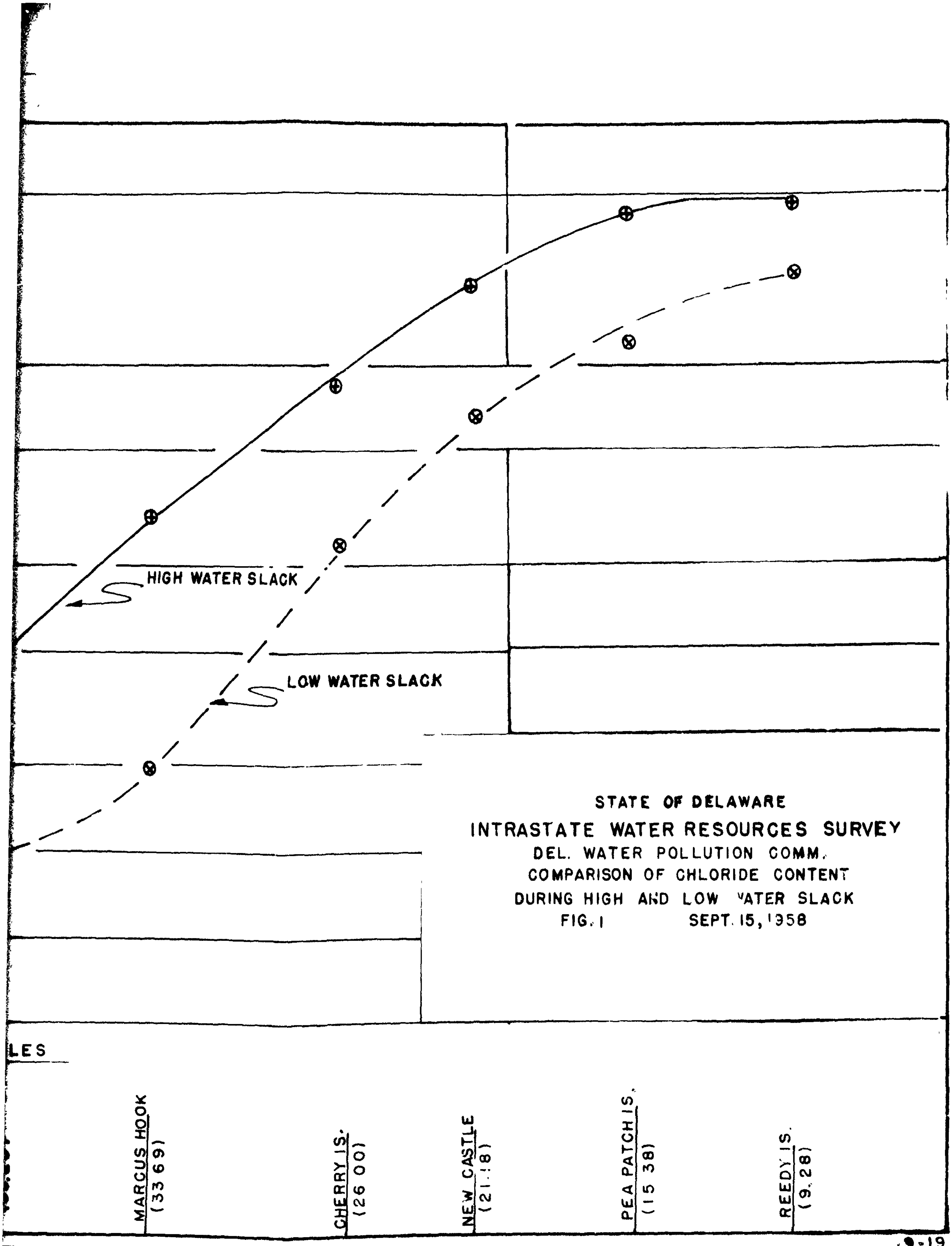
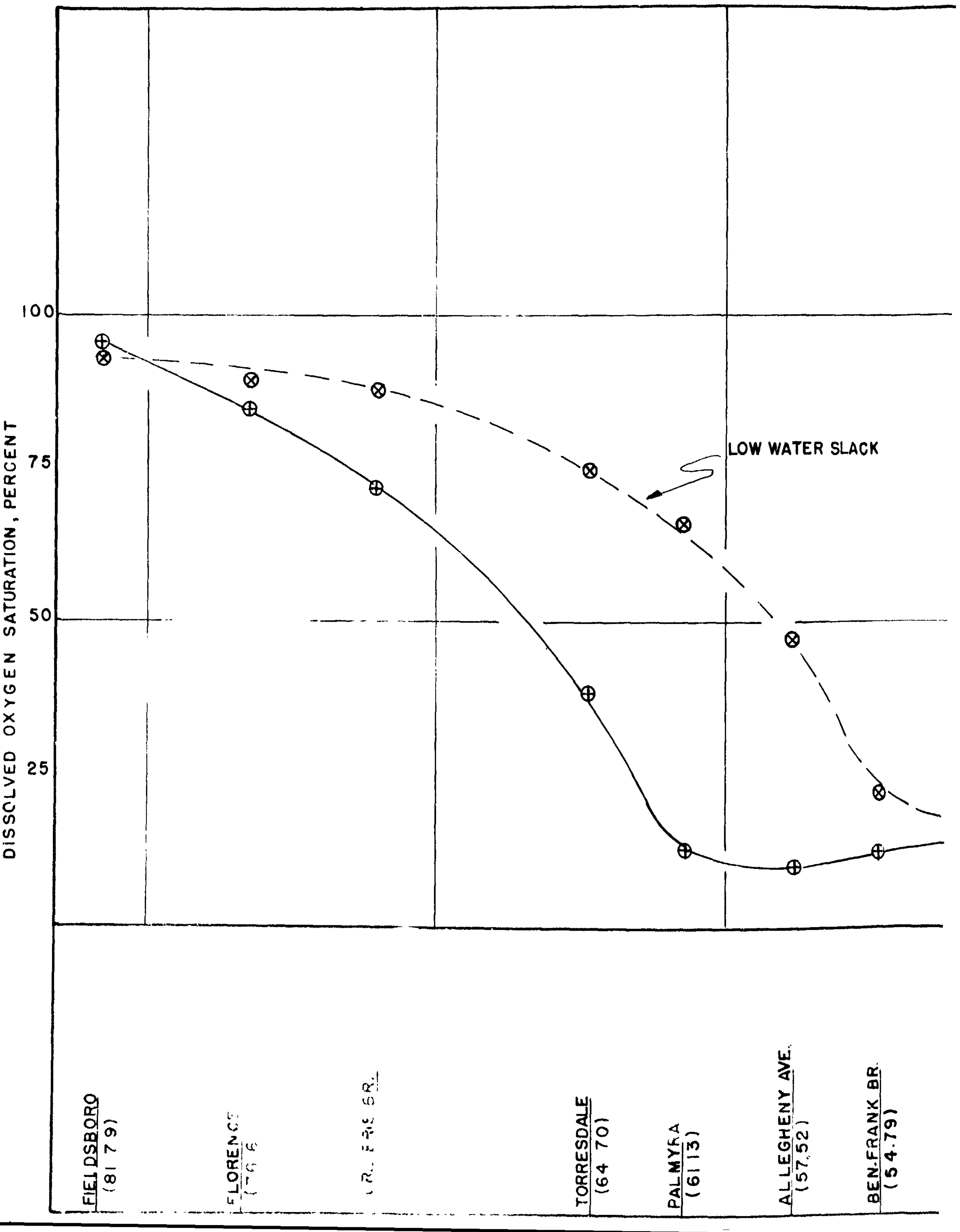


CHLORIDES, P.P.M.
,000
1,000
500
200
100
40
20
10
5
D
FIELDSBORO (81.79)
FLORENCE (76.66)
BURL. BRIS. BR. (72.11)
TORRESDALE (64.70)
PALMYRA (61.13)
ALLEGHENY AVE. (57.52)
BEN FRANK BR. (54.79)

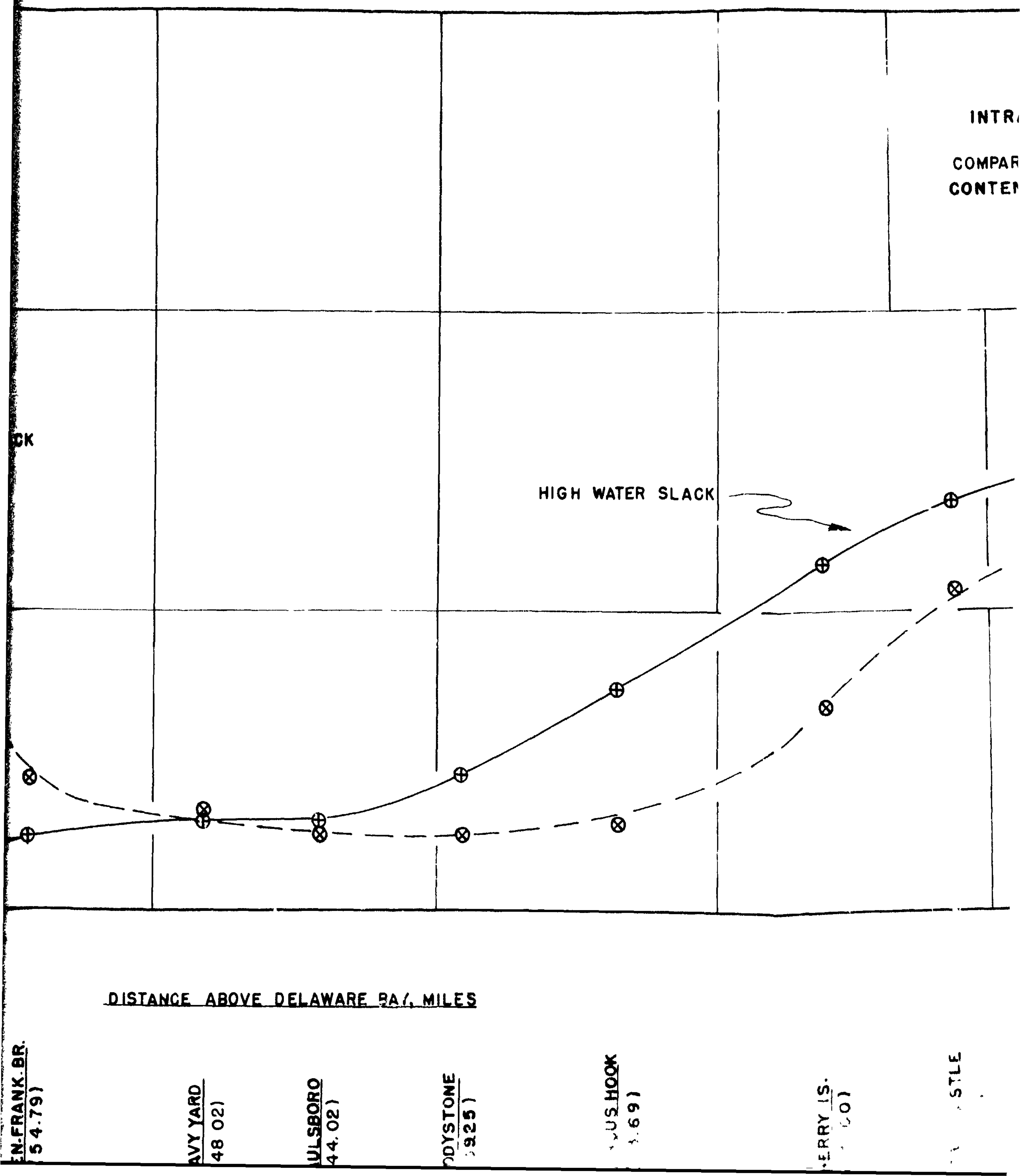


HIGH WATER SLACK
LOW WATER SLACK
INT
DISTANCE ABOVE DELAWARE BAY, MILES
BEN FRANK BR. (54.79)
NAVY YARD (48.02)
PAULSBORO (44.02)
EDDYSTONE (39.25)
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)

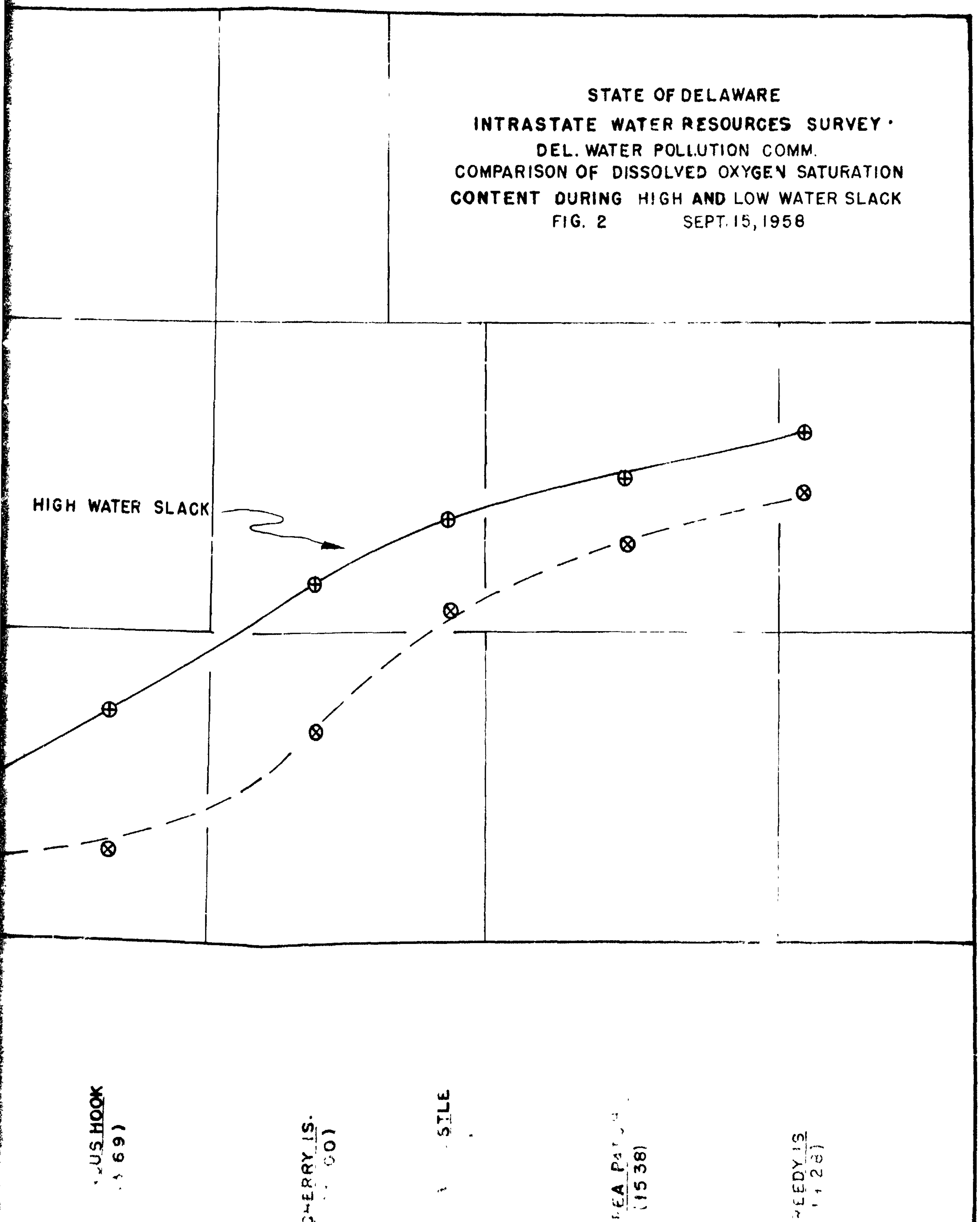

HIGH WATER SLACK
LOW WATER SLACK
STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DEL. WATER POLLUTION COMM.
COMPARISON OF CHLORIDE CONTENT
DURING HIGH AND LOW WATER SLACK
FIG. I SEPT. 15, 1958
LES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)

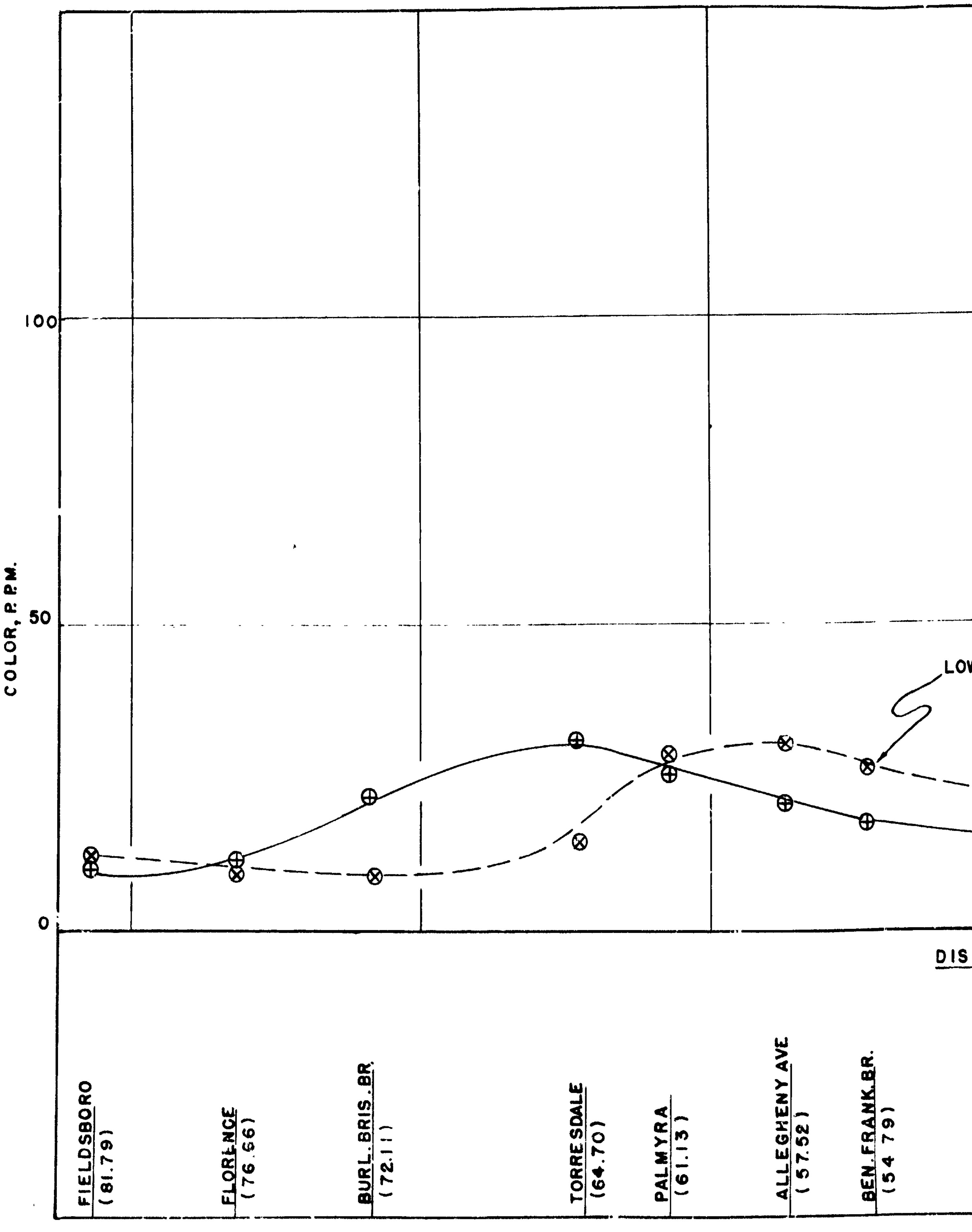


100
75
50
25
DISSOLVED OXYGEN SATURATION, PERCENT
LOW WATER SLACK
FIELDSBORO (81 79)
TORRESDALE (64 70)
PALMYRA (61 13)
ALLEGHENY AVE. (57,52)
BEN. FRANK BR. (54.79)

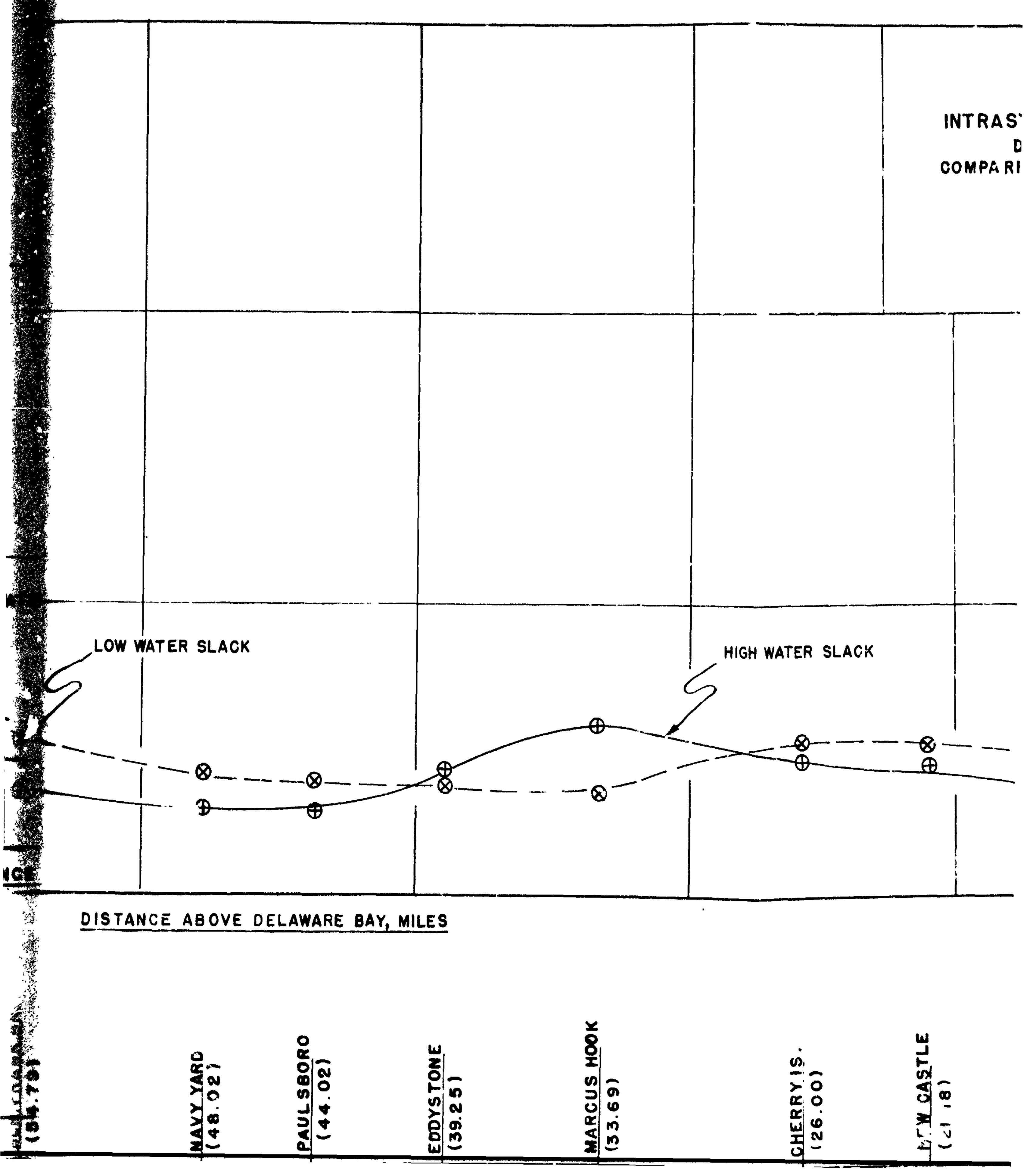


INTR
COMPAR
CONTEN
CK
HIGH WATER SLACK
DISTANCE ABOVE DELAWARE BAY, MILES
EN.FRANK.BR.
(54.79)
AVY YARD
(48.02)
ULSBORO
(44.02)
ODYSTONE
US HOOK

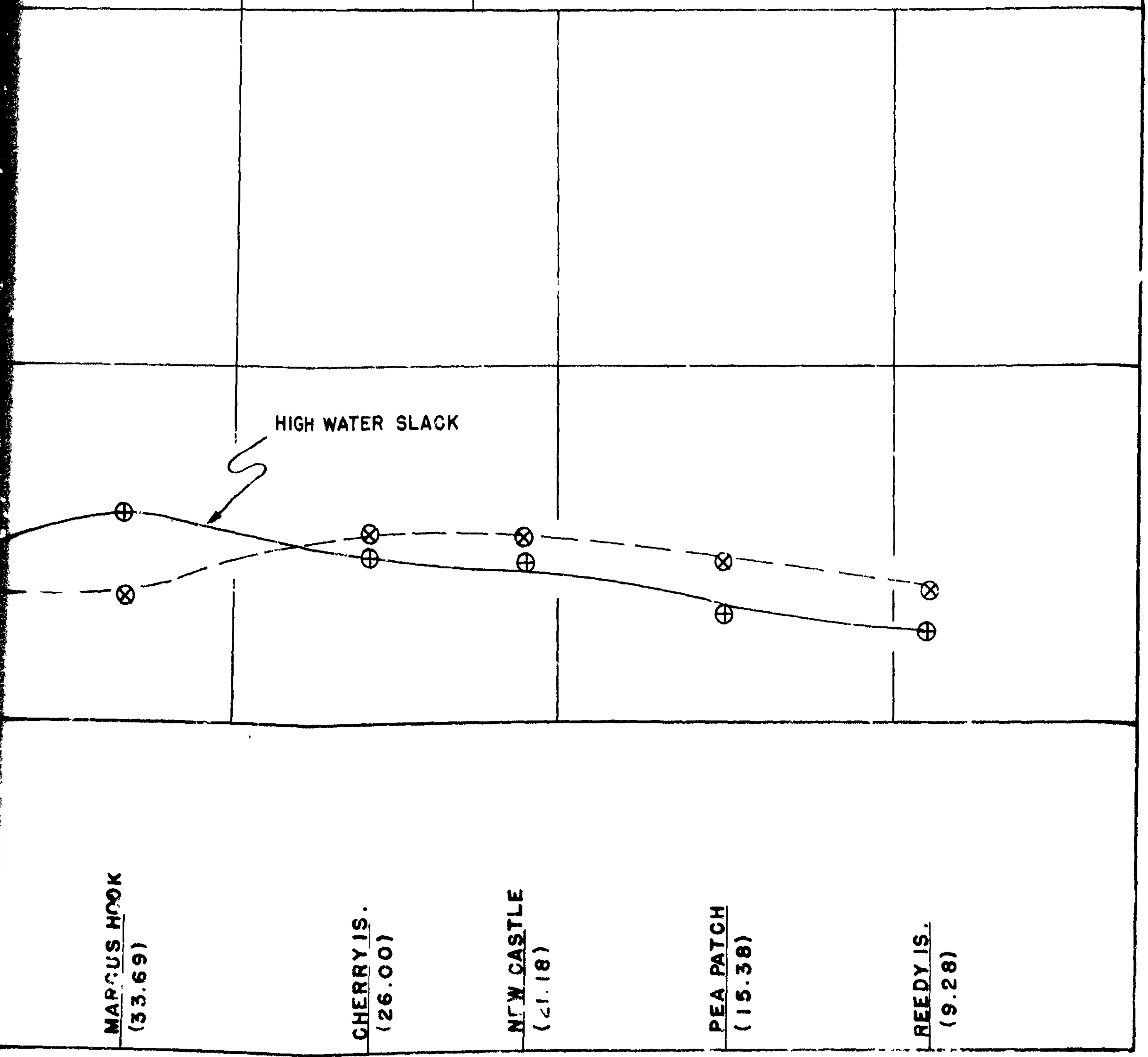

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DEL. WATER POLLUTION COMM.
COMPARISON OF DISSOLVED OXYGEN SATURATION
CONTENT DURING HIGH AND LOW WATER SLACK
FIG. 2 SEPT. 15, 1958
HIGH WATER SLACK

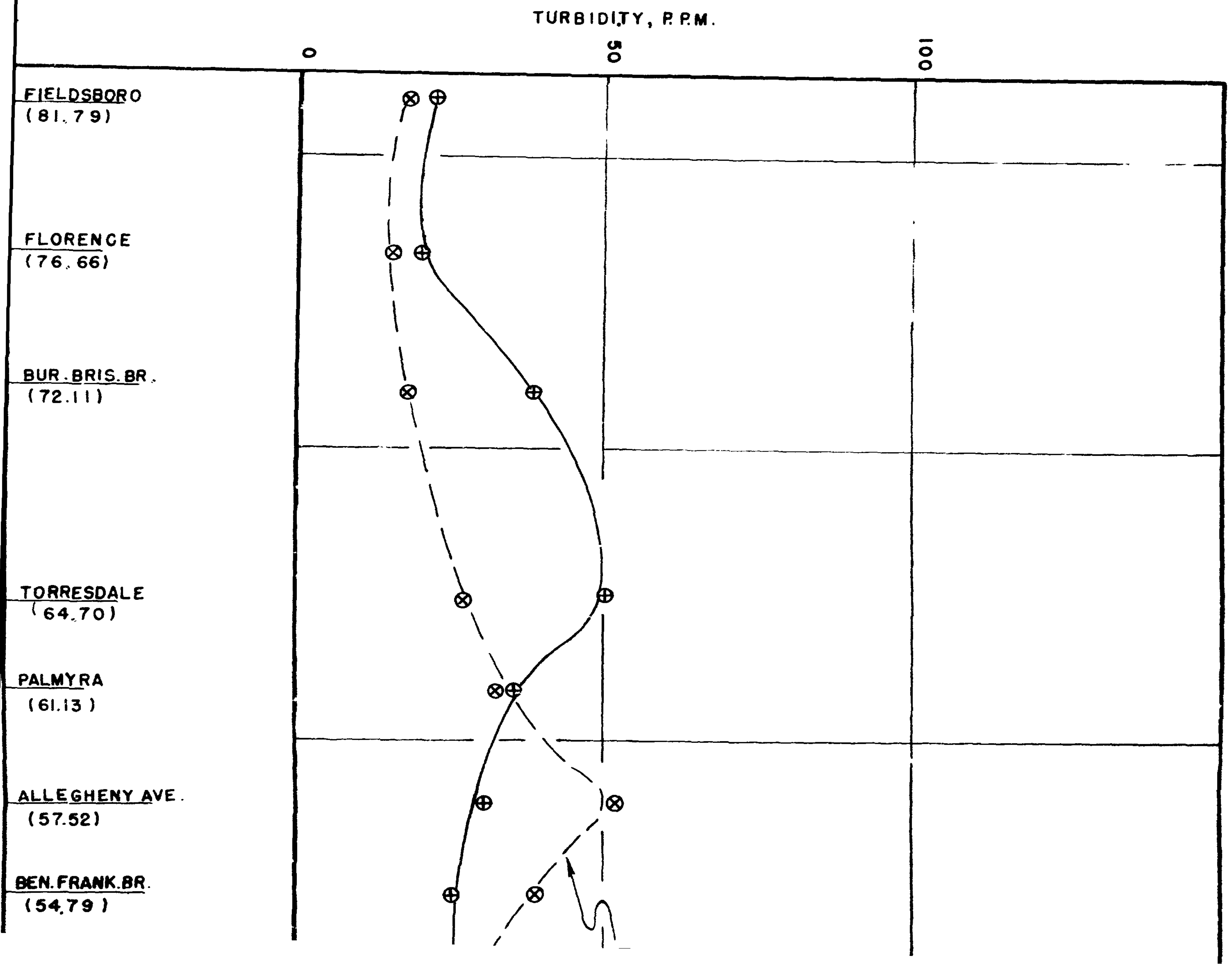


COLOR, P.P.M.
100
50
0
LOW
DIS
FIELDSBORO (81.79)
FLORENCE (76.66)
BURL. BRIS. BR. (72.11)
TORRESDALE (64.70)
PALMYRA (61.13)
ALLEGHENY AVE (57.52)
BEN. FRANK. BR. (54.79)

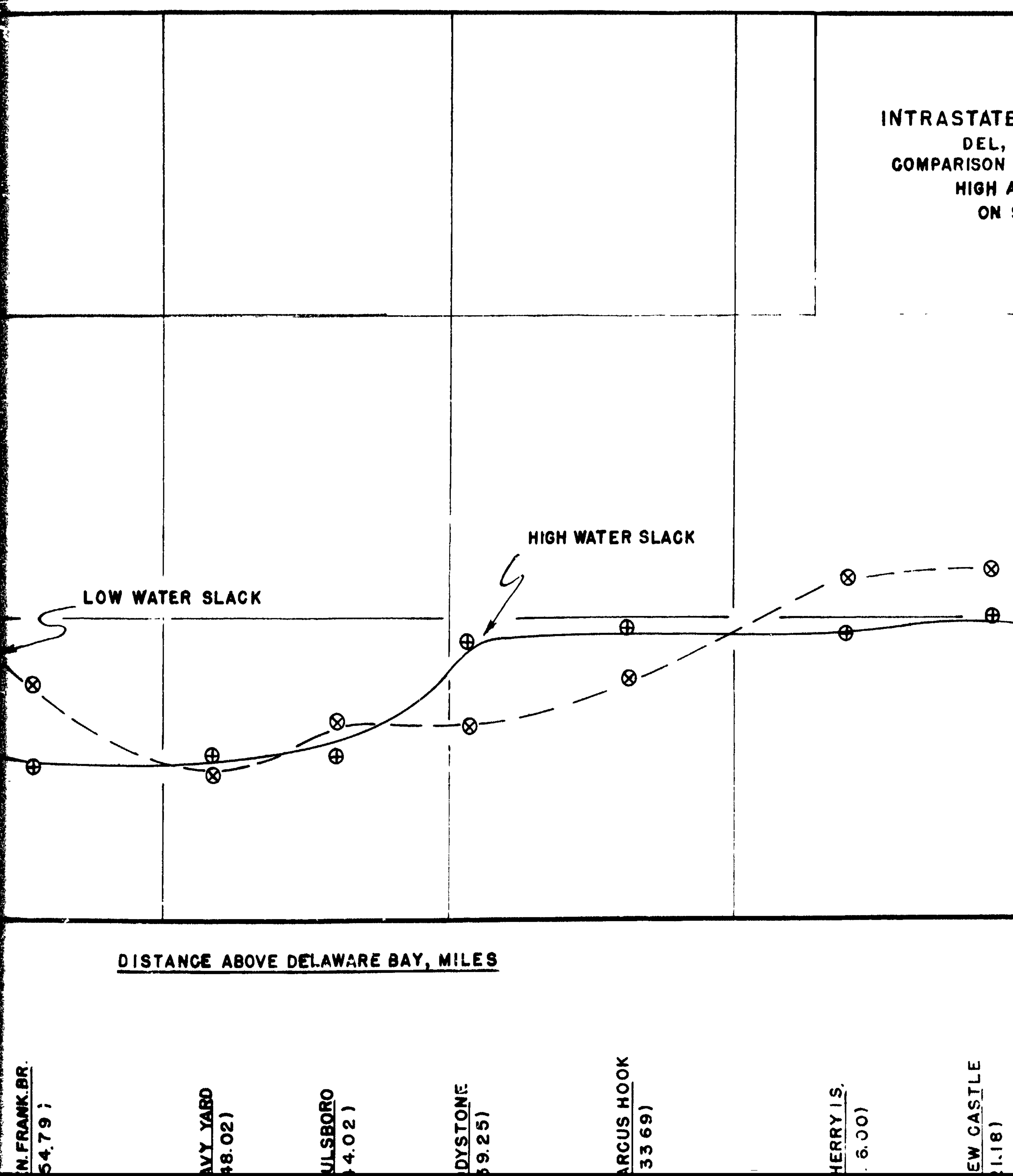

LOW WATER SLACK
HIGH WATER SLACK
DISTANCE ABOVE DELAWARE BAY, MILES
NAVY YARD (48.02)
PAULSBORO (44.02)
EDDYSTONE (39.25)
MARCUS HOOK (33.69)
CHERRY IS. (26.00)

STATE OF DELAWARE
INTRASTATE WATER RESOURCE SURVEY
DEL. WATER POLLUTION COMM.
COMPARISON OF COLOR CONTENT DURING HIGH AND LOW WATER SLACK
ON SEPTEMBER 15, 1958
FIG. 3

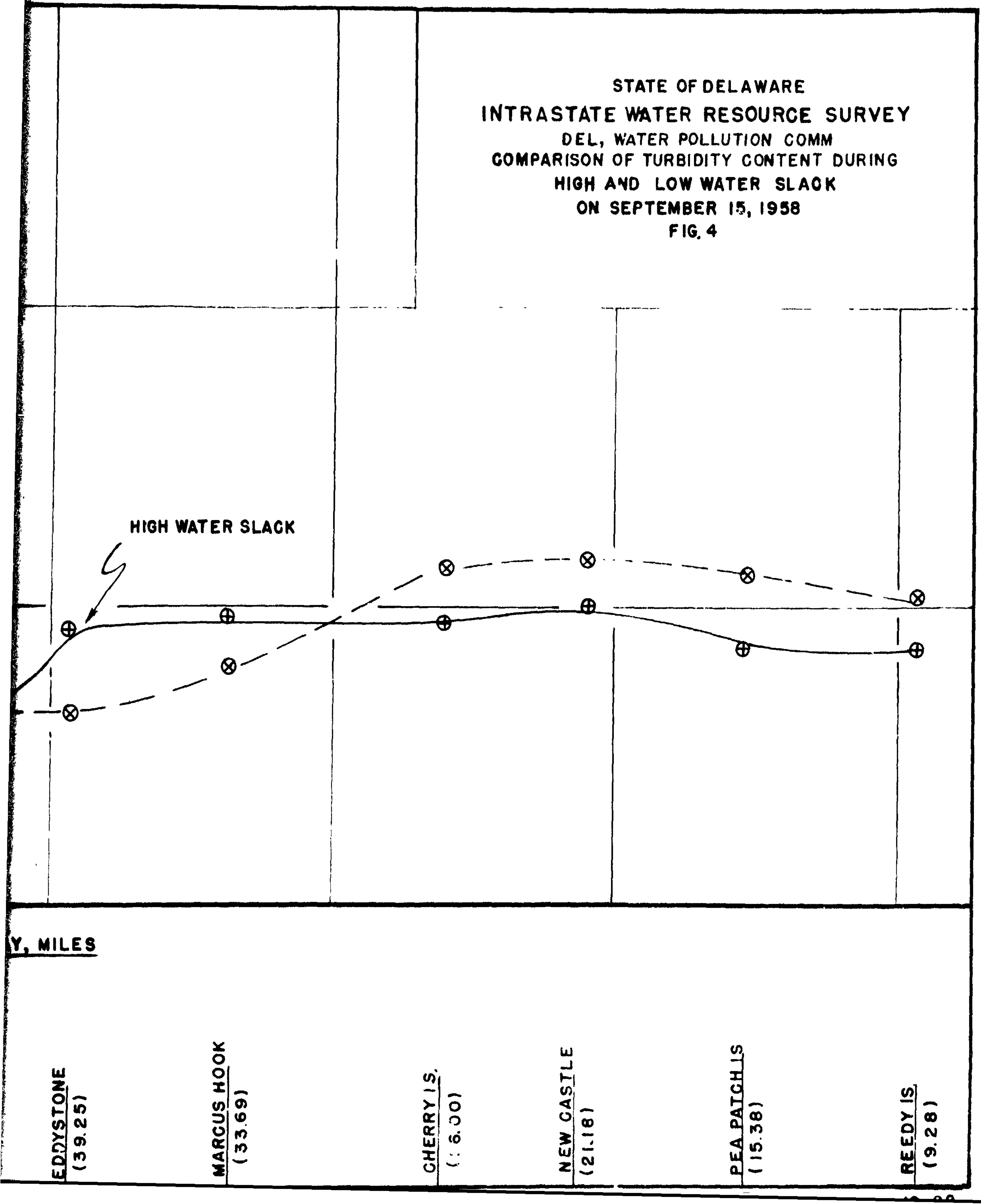


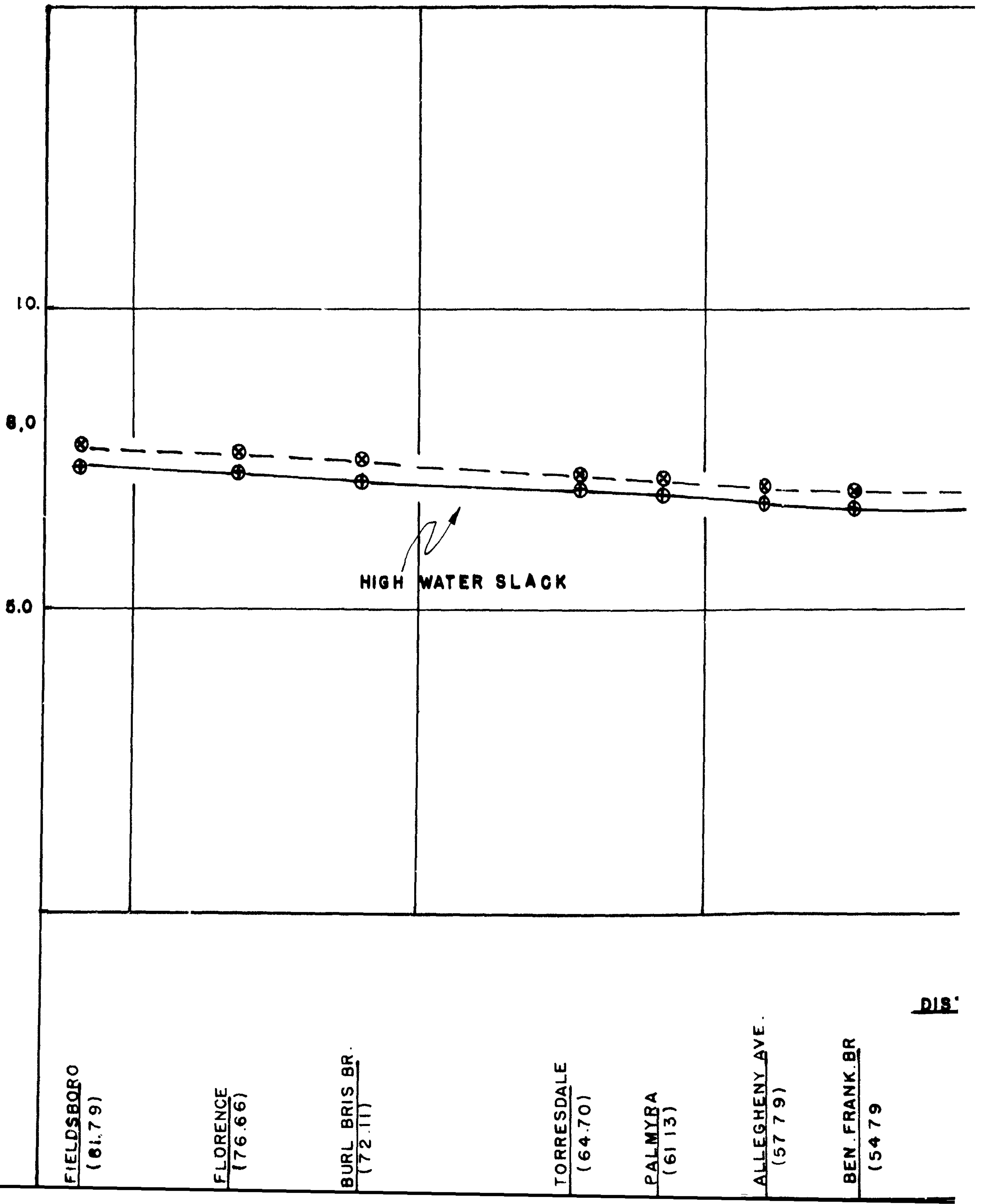


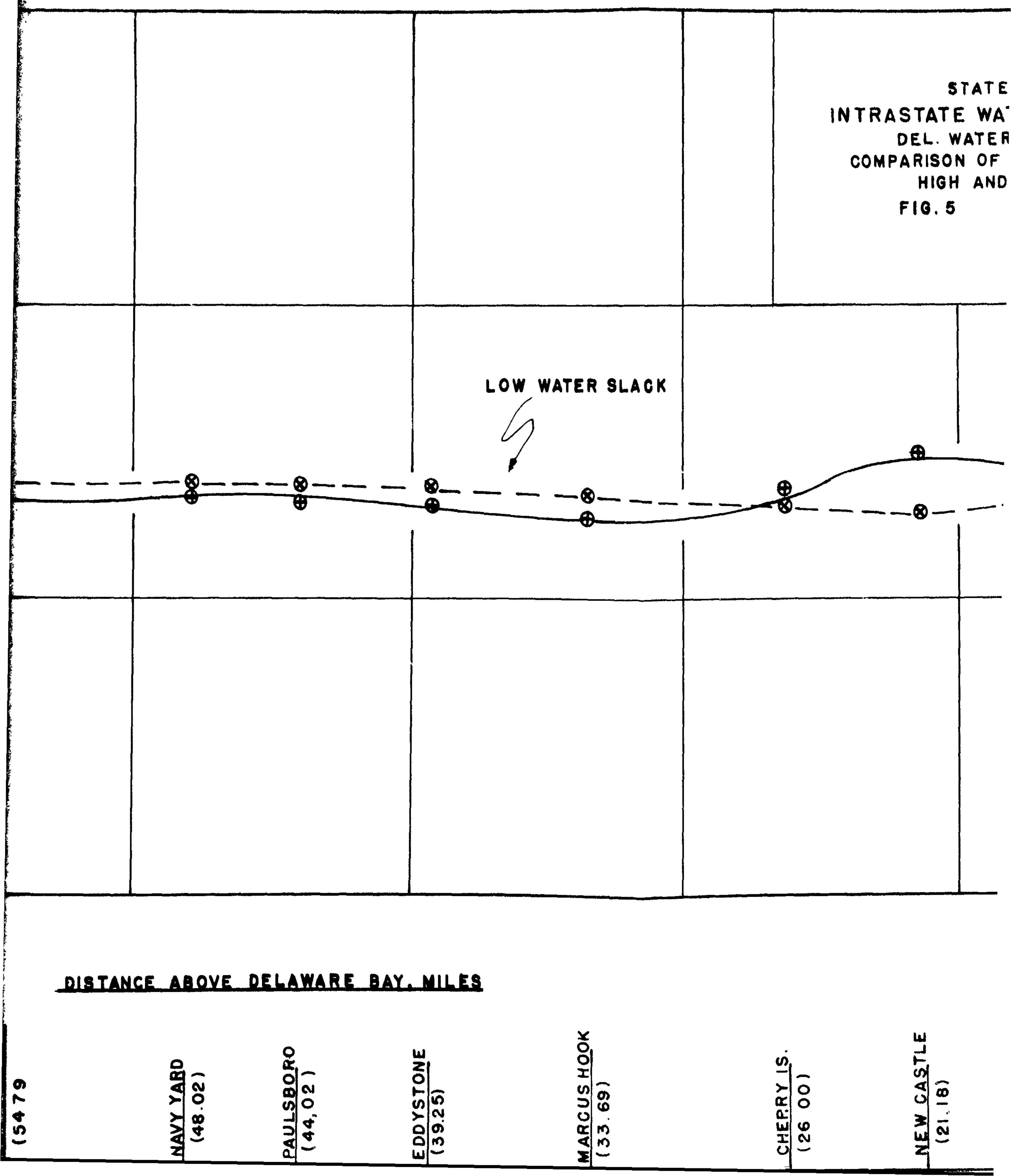
TURBIDITY, P.P.M.
0
50
100
FIELDSBORO (81.79)
FLORENCE (76.66)
BUR. BRIS. BR. (72.11)
TORRESDALE (64.70)
PALMYRA (61.13)
ALLEGHENY AVE. (57.52)
BEN. FRANK. BR. (54.79)

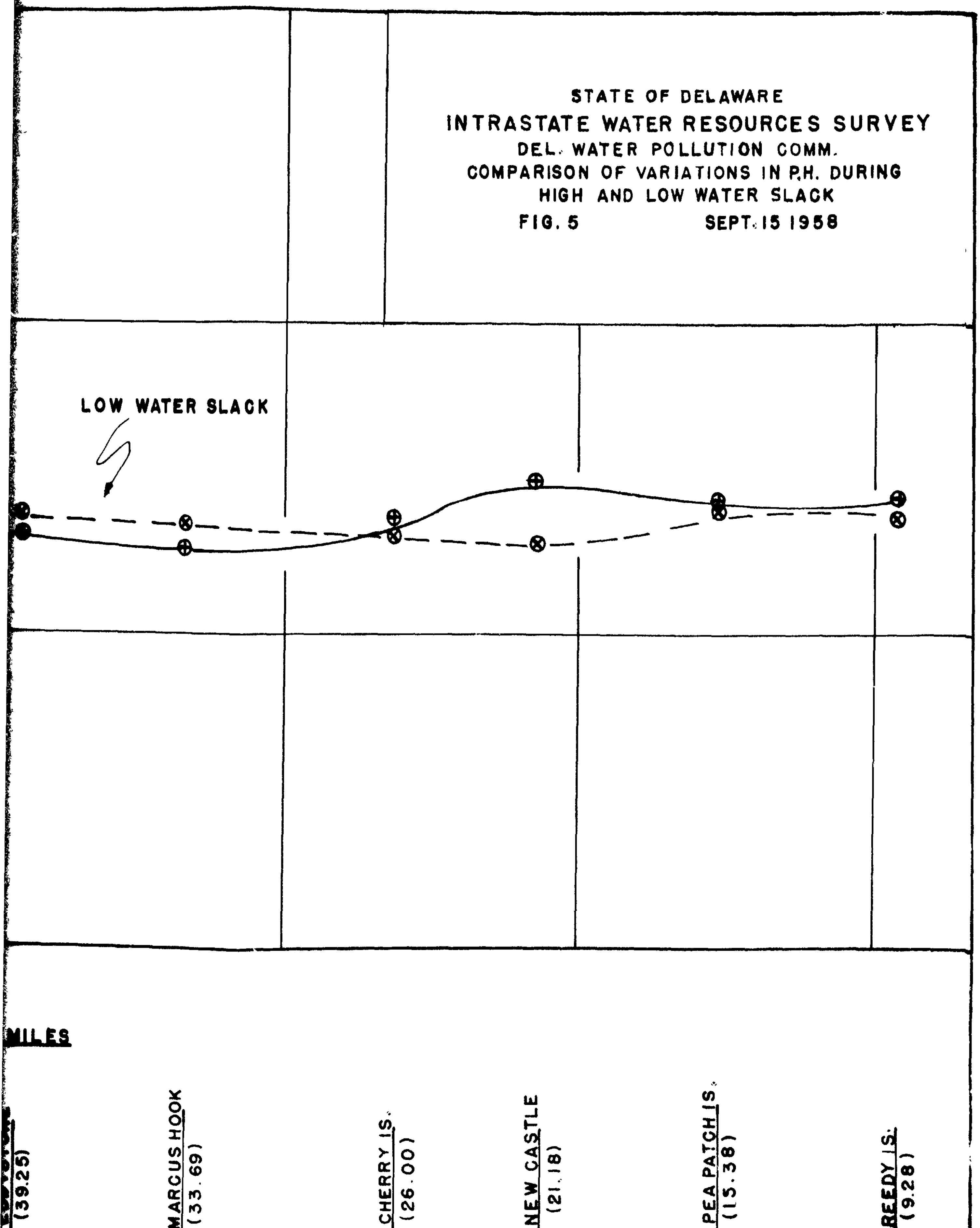


INTRASTATE
DEL,
COMPARISON
HIGH A
ON
HIGH WATER SLACK
LOW WATER SLACK
DISTANCE ABOVE DELAWARE BAY, MILES
N.FRANK.BR. 54.79
AVY YARD 48.02)
ULSBORO 4.02)
DYSTONE 39.25)
ARCUS HOOK 33 69)
HERRY IS. 6.00)
EW CASTLE 1.18)

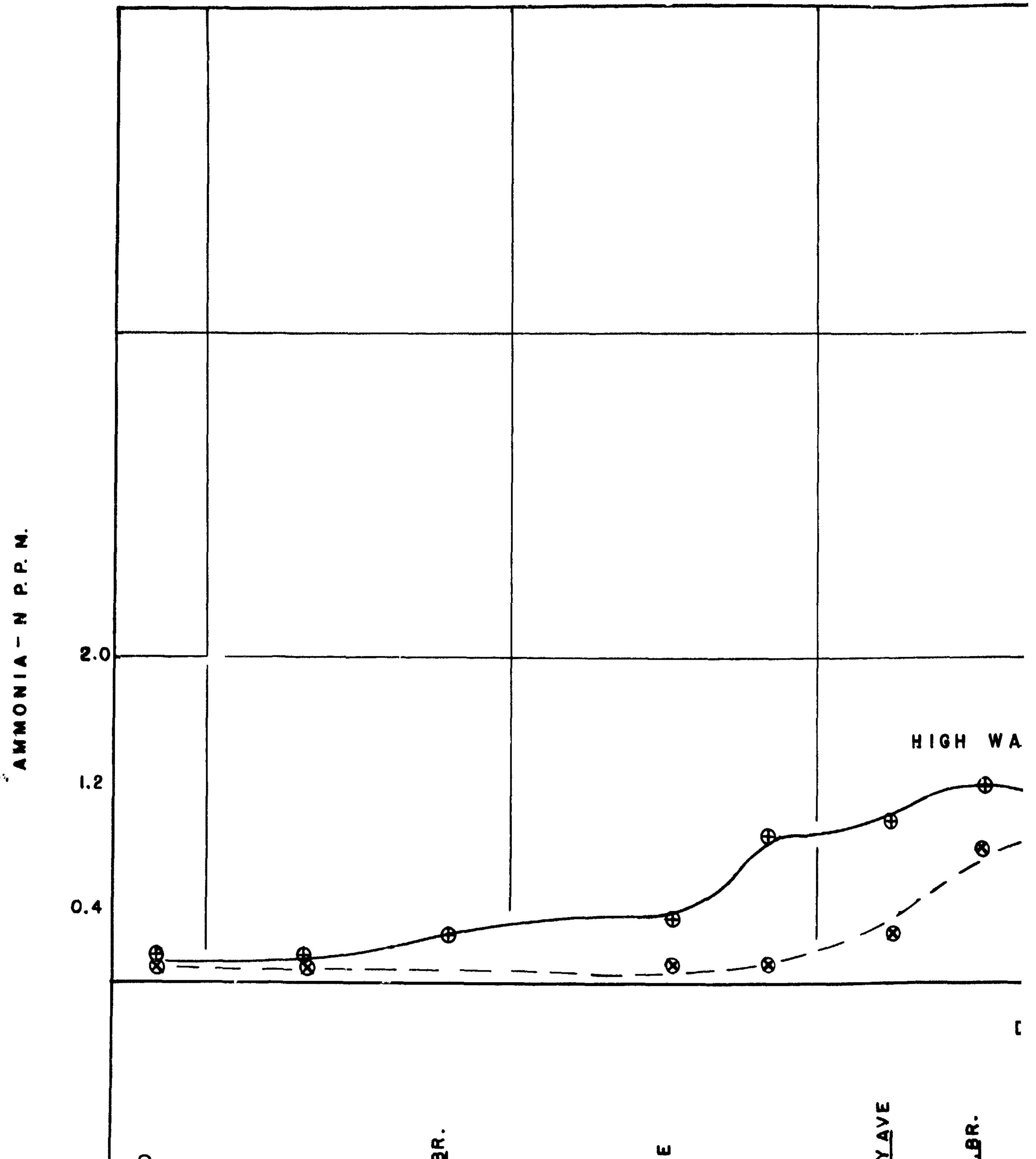

STATE OF DELAWARE
INTRASTATE WATER RESOURCE SURVEY
DEL, WATER POLLUTION COMM
COMPARISON OF TURBIDITY CONTENT DURING
HIGH AND LOW WATER SLACK
ON SEPTEMBER 15, 1958
FIG. 4
HIGH WATER SLACK
Y, MILES
EDDYSTONE (39.25)
MARCUS HOOK (33.69)
CHERRY IS.
NEW CASTLE (21.18)
PEA PATCH IS (15.38)
REEDY IS (9.28)

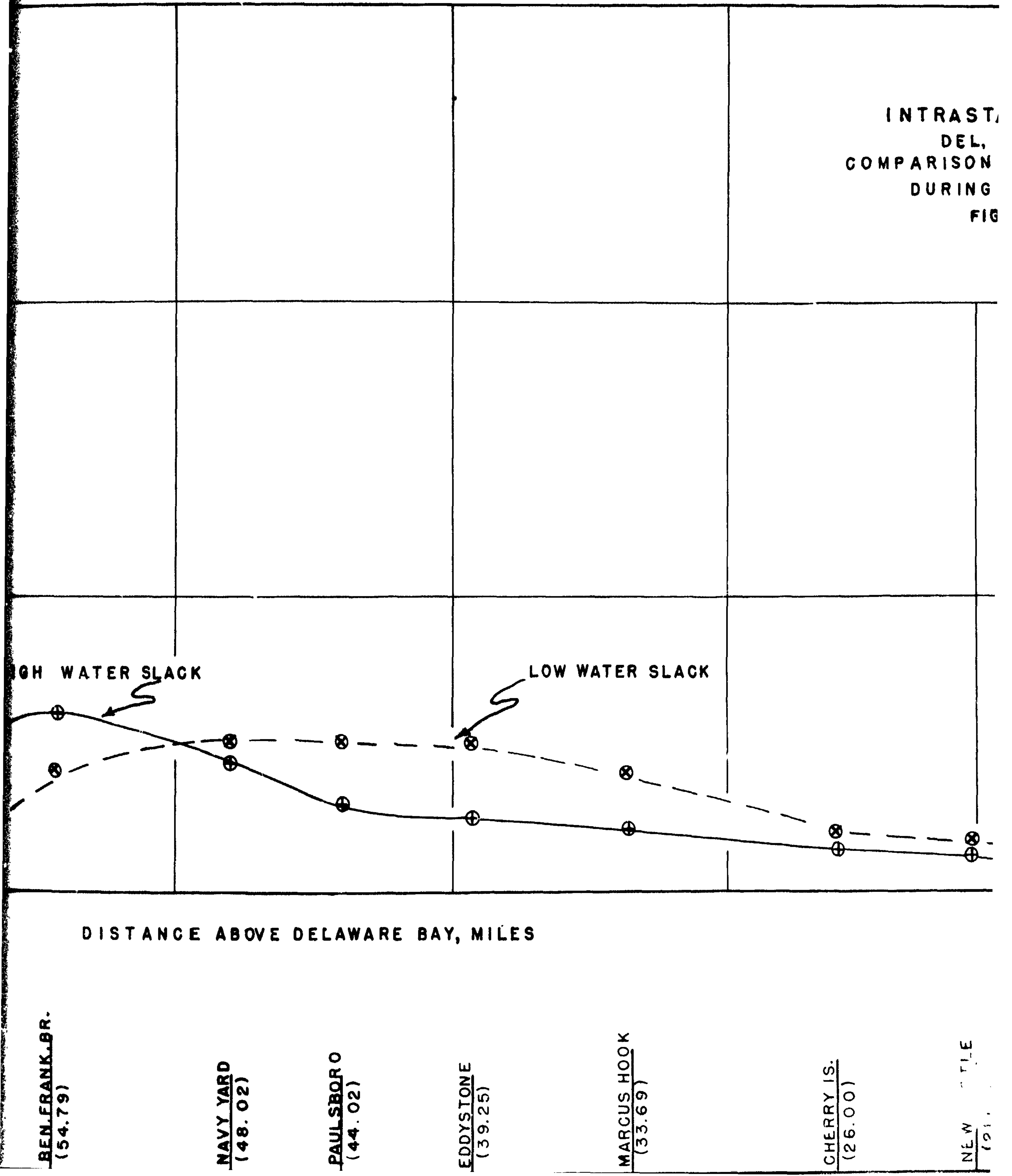

10.
8,0
5.0
HIGH WATER SLACK
FIELDSBORO (81.79)
FLORENCE (76.66)
BURL BRIS BR. (72.11)
TORRESDALE (64.70)
PALMYRA (61 13)
ALLEGHENY AVE. (57 79)
BEN. FRANK BR (54 79


STATE
INTRASTATE WA
DEL. WATER
COMPARISON OF
HIGH AND
FIG. 5
LOW WATER SLACK
DISTANCE ABOVE DELAWARE BAY, MILES
(54.79
NAVY YARD (48.02)
PAULSBORO (44,02)
EDDYSTONE (39.25)
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DEL. WATER POLLUTION COMM.
COMPARISON OF VARIATIONS IN P.H. DURING
HIGH AND LOW WATER SLACK
FIG. 5 SEPT. 15 1958


AMMONIA - N P.P.M.
2.0
1.2
0.4
HIGH WA
FIELDSBORO (81.79)
FLORENCE (76.66)
RIS. BR.
TORRESDALE (64.70)
PALMYRA (61.13)
ALLEGHENY AVE (57.52)
BEN. FRANK. BR. (54.79)


INTRAST
DEL,
COMPARISON
DURING
FIG
IGH WATER SLACK
LOW WATER SLACK
DISTANCE ABOVE DELAWARE BAY, MILES
BEN.FRANK.BR. (54.79)
NAVY YARD (48.02)
PAULSBORO (44.02)
EDDYSTONE (39.25)
MARCUS HOOK (33.69)
CHERRY IS. (26.00)

STATE OF DELAWARE

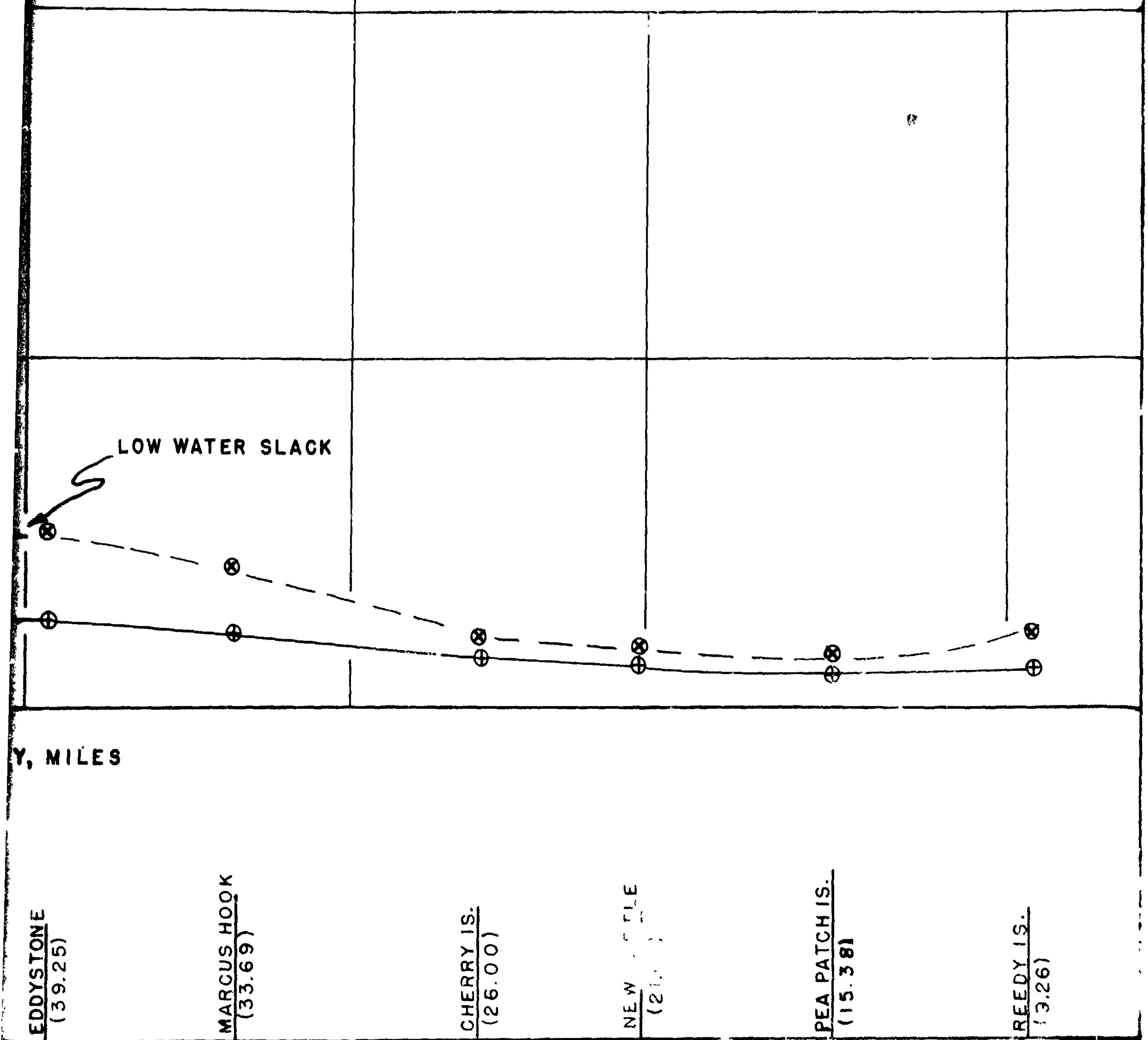
INTRASTATE WATER RESOURCE SURVEY

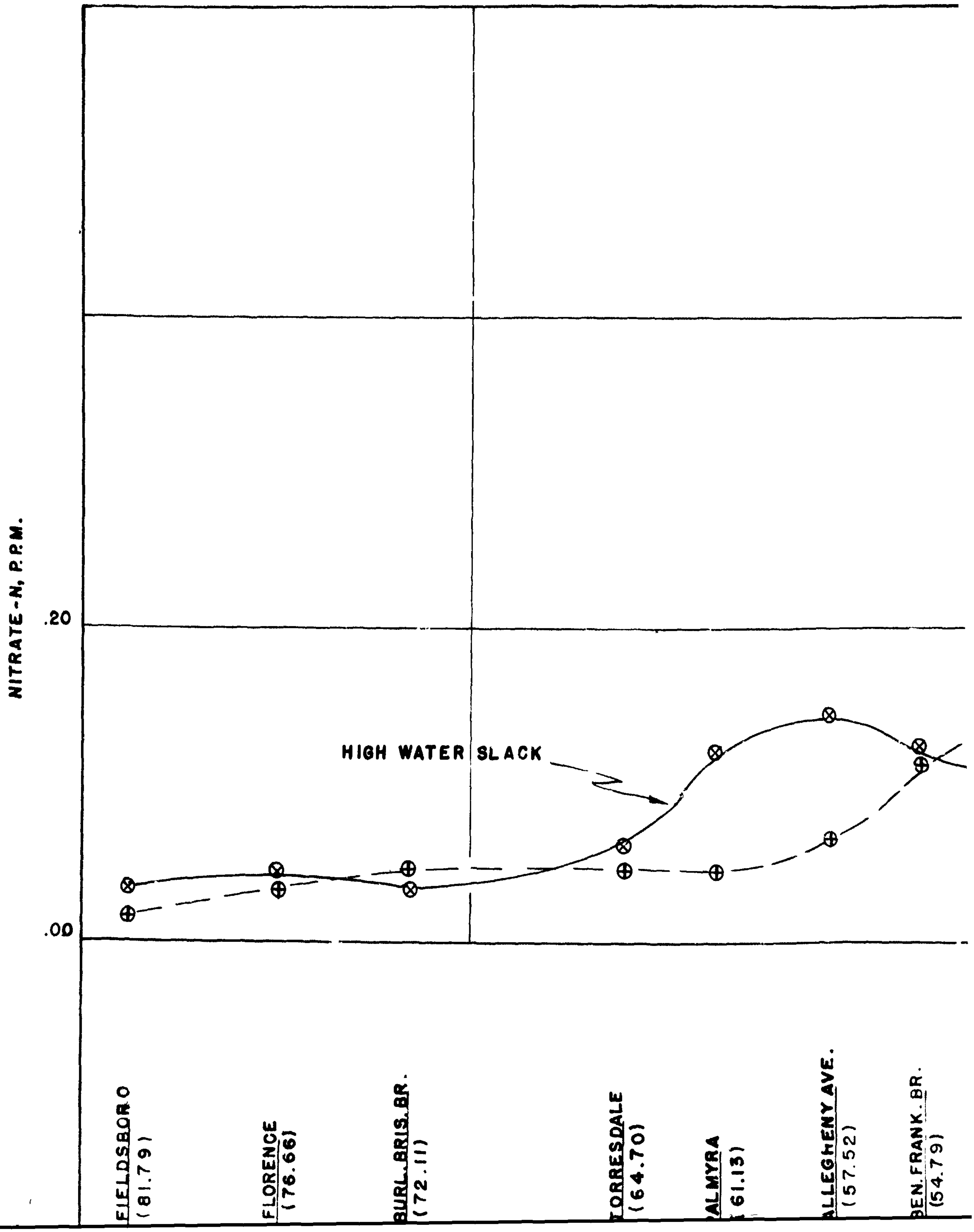
DEL. WATER POLLUTION COMM.

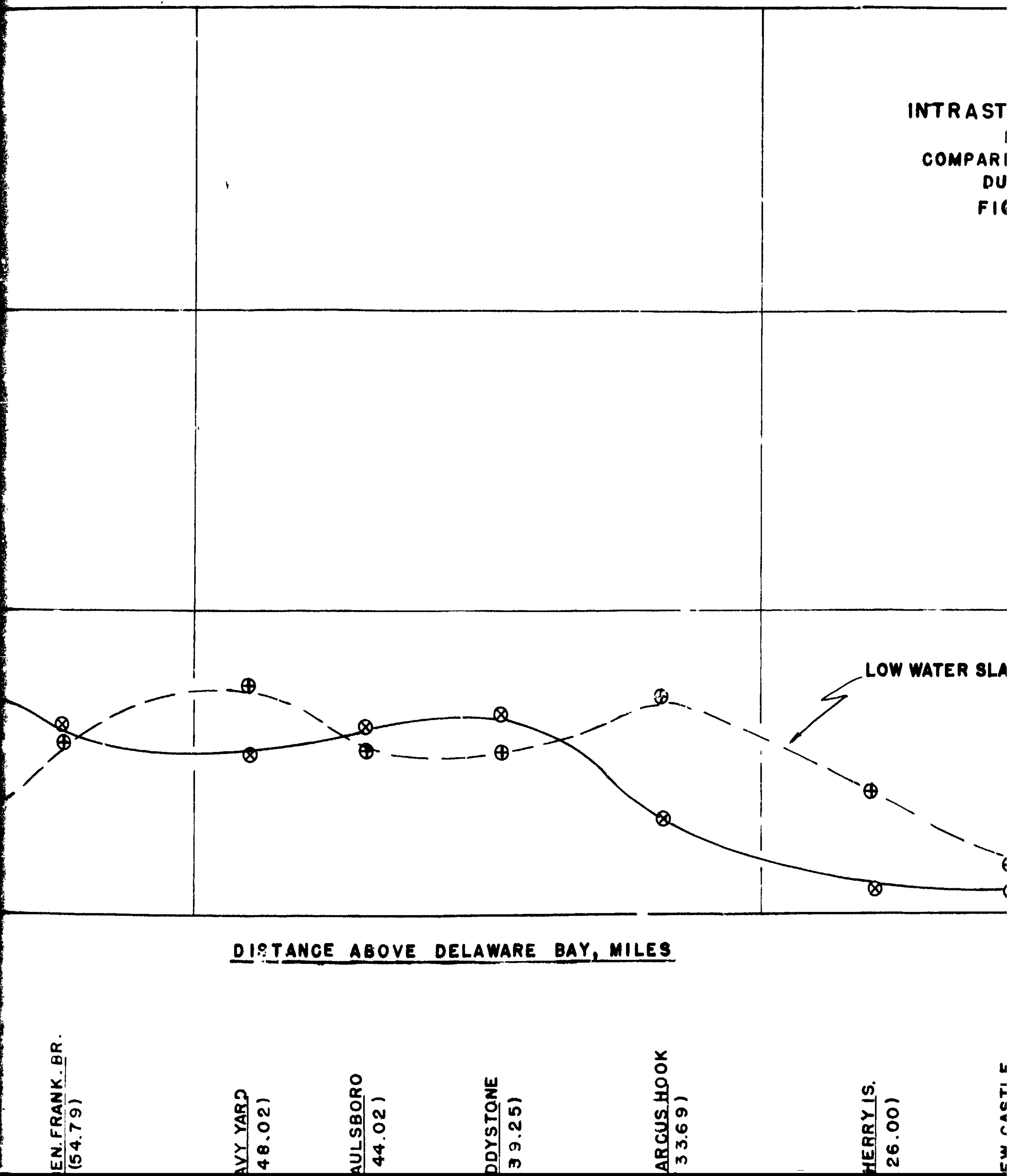
COMPARISON OF AMMONIA-NITROGEN CONTENT

DURING HIGH AND LOW WATER SLACK

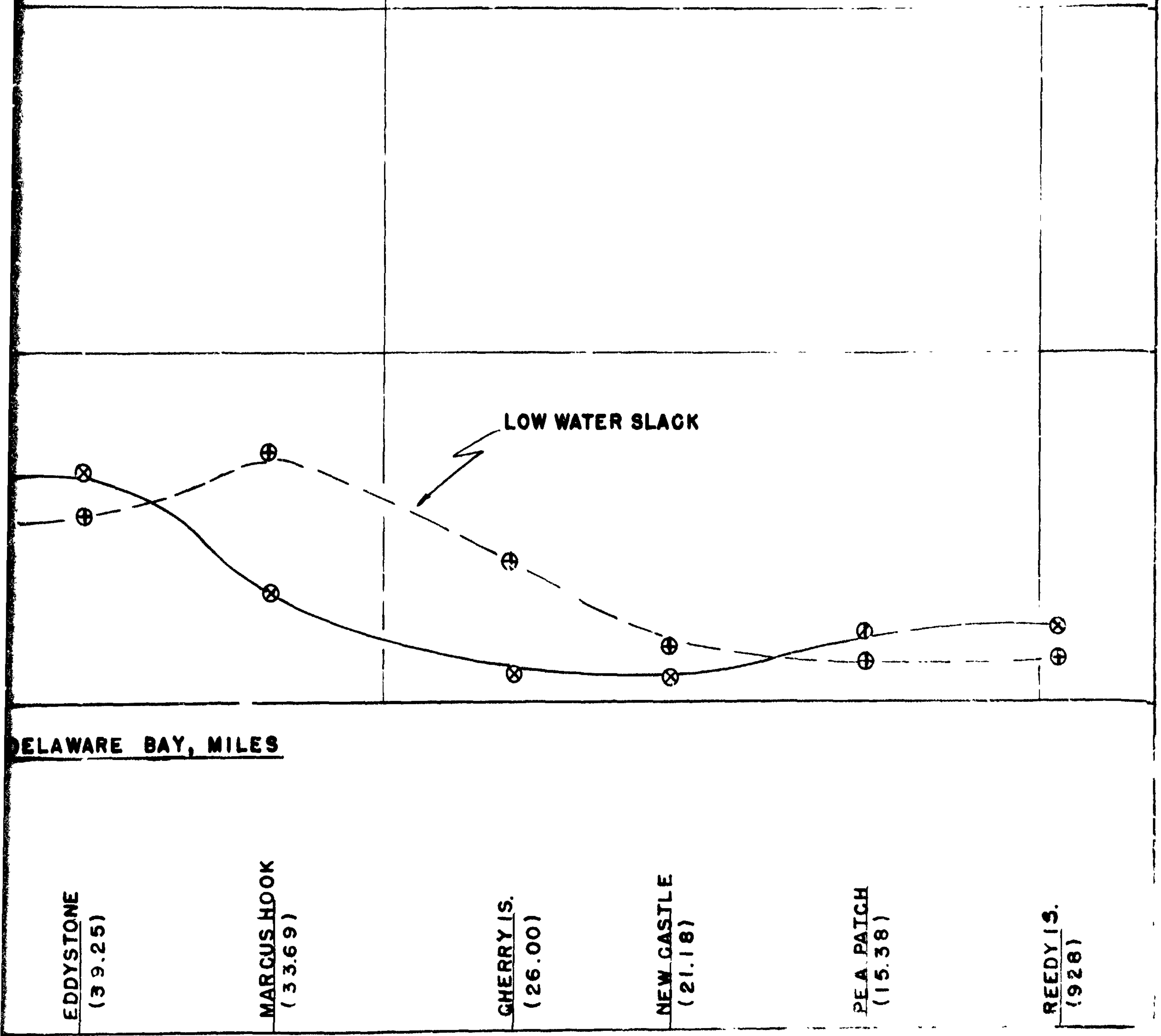
FIG. 6 SEPT. 15, 1958

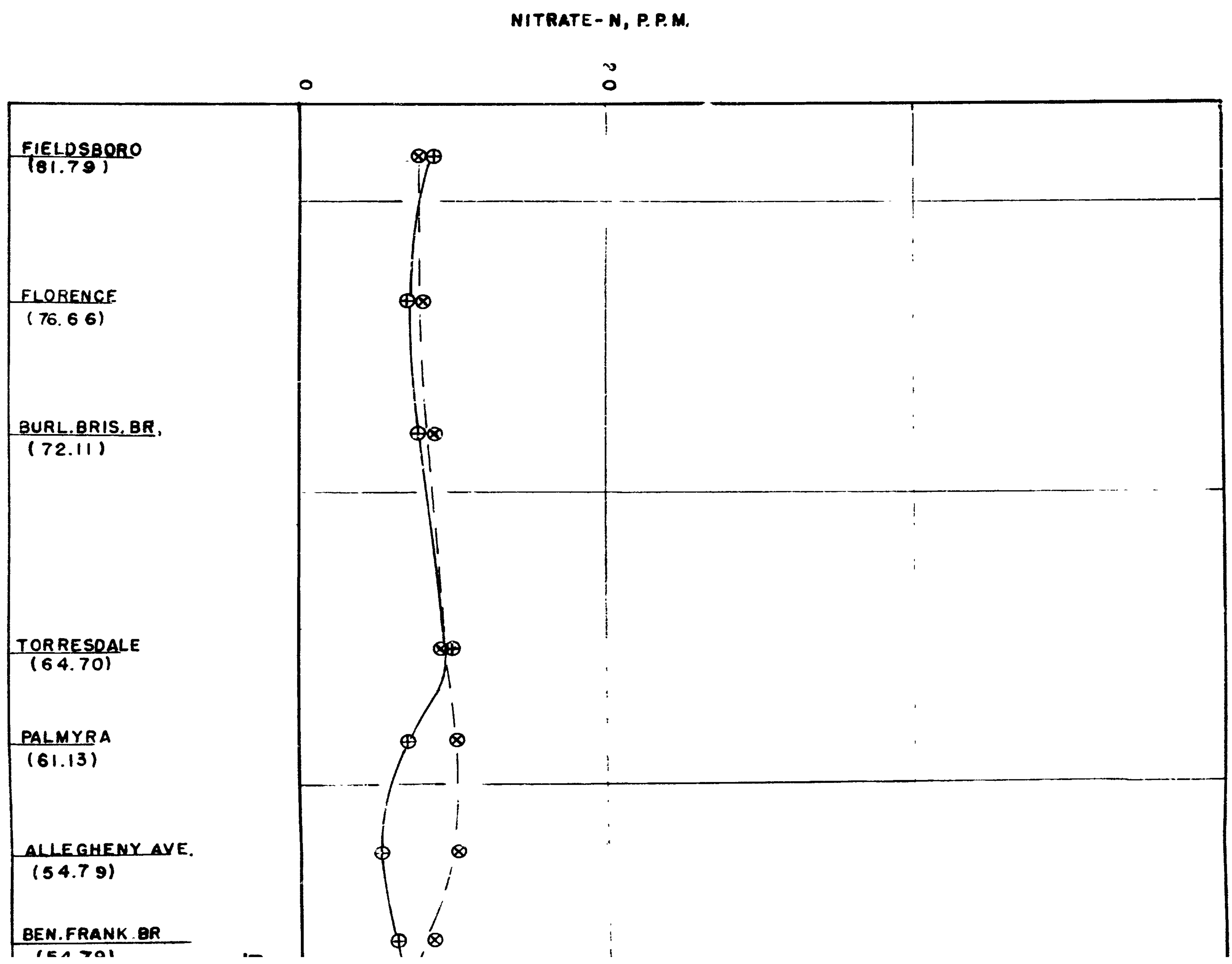


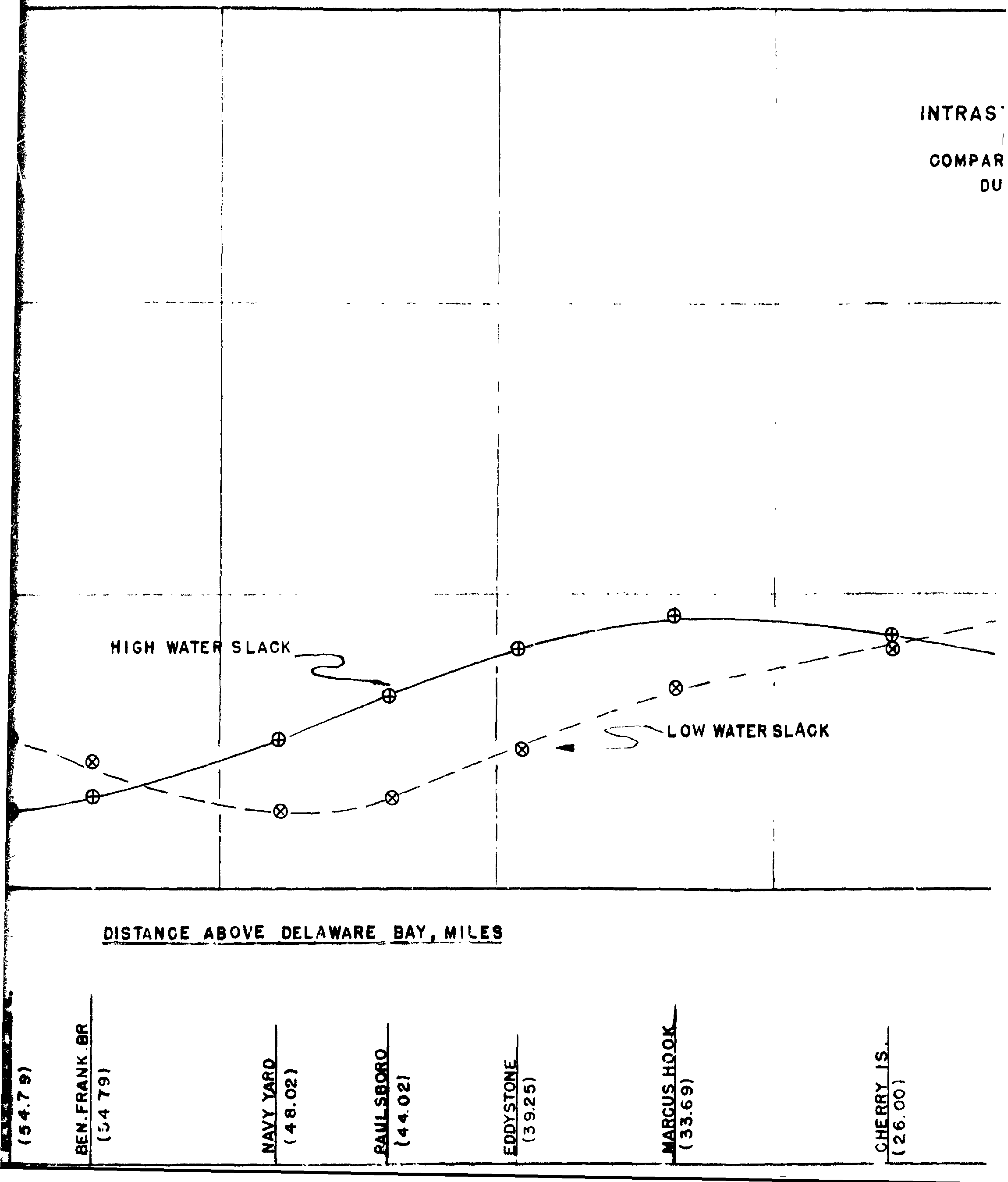

NITRATE-N, P.P.M.
.20
.00
HIGH WATER SLACK
FIELDSBORO (81.79)
FLORENCE (76.66)
BURL. BRIS. BR. (72.11)
TORRESDALE (64.70)
PALMYRA (61.13)
ALLEGHENY AVE. (57.52)
BEN. FRANK. BR. (54.79)

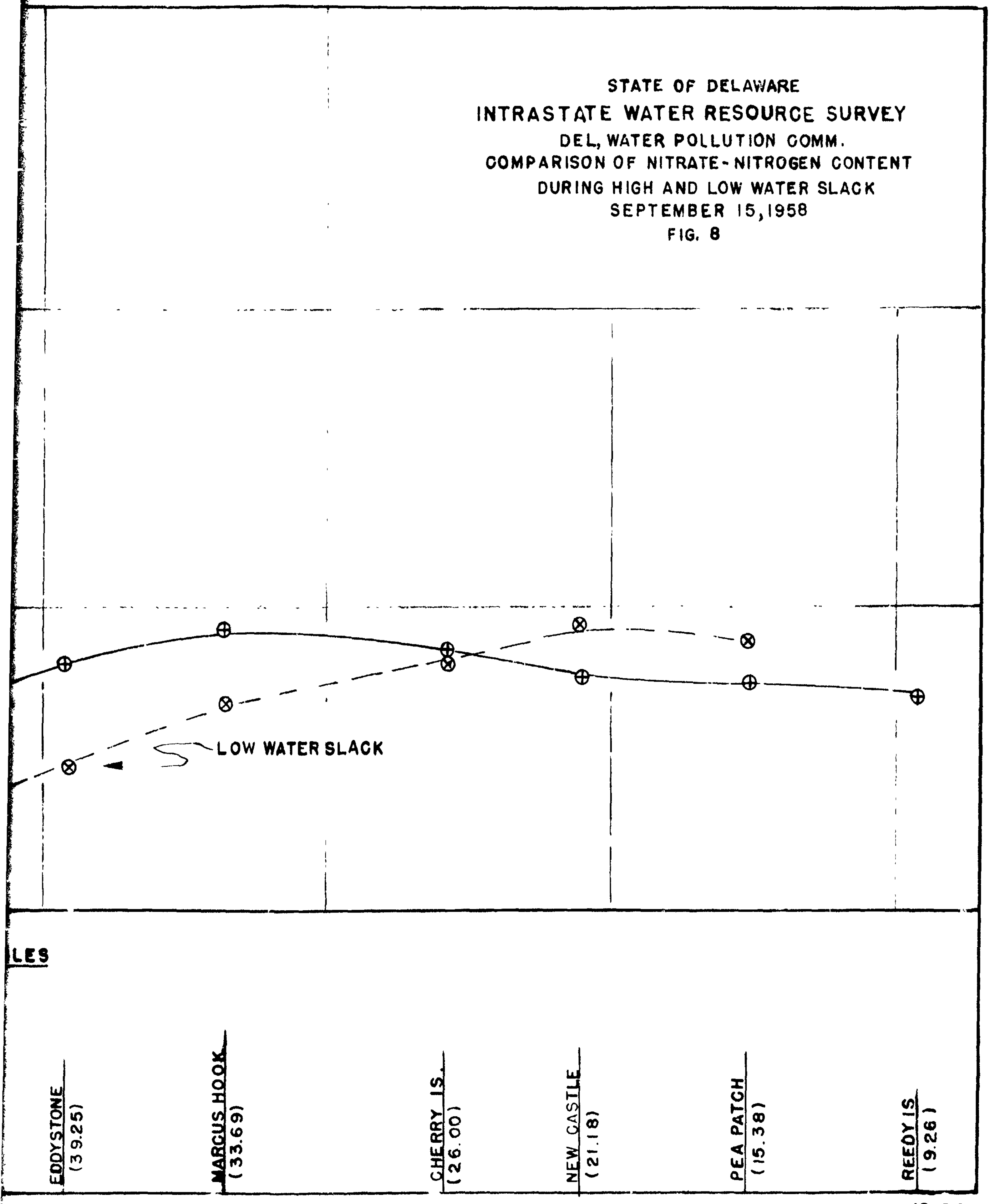

INTRAST
COMPARI
DU
LOW WATER SLA
DISTANCE ABOVE DELAWARE BAY, MILES
EN.FRANK.BR. (54.79)
AVY YARD (48.02)
AULSBORO (44.02)
DDYSTONE (39.25)
ARCUS HOOK (33.69)
HERRY IS. (26.00)

STATE OF DELAWARE
INTRASTATE WATER RESOURCE SURVEY
DEL, WATER POLLUTION COMM.
COMPARISON OF NITRATE-NITROGEN CONTENT
DURING HIGH AND LOW WATER SLACK
FIG. 7 SEPT. 15, 1958

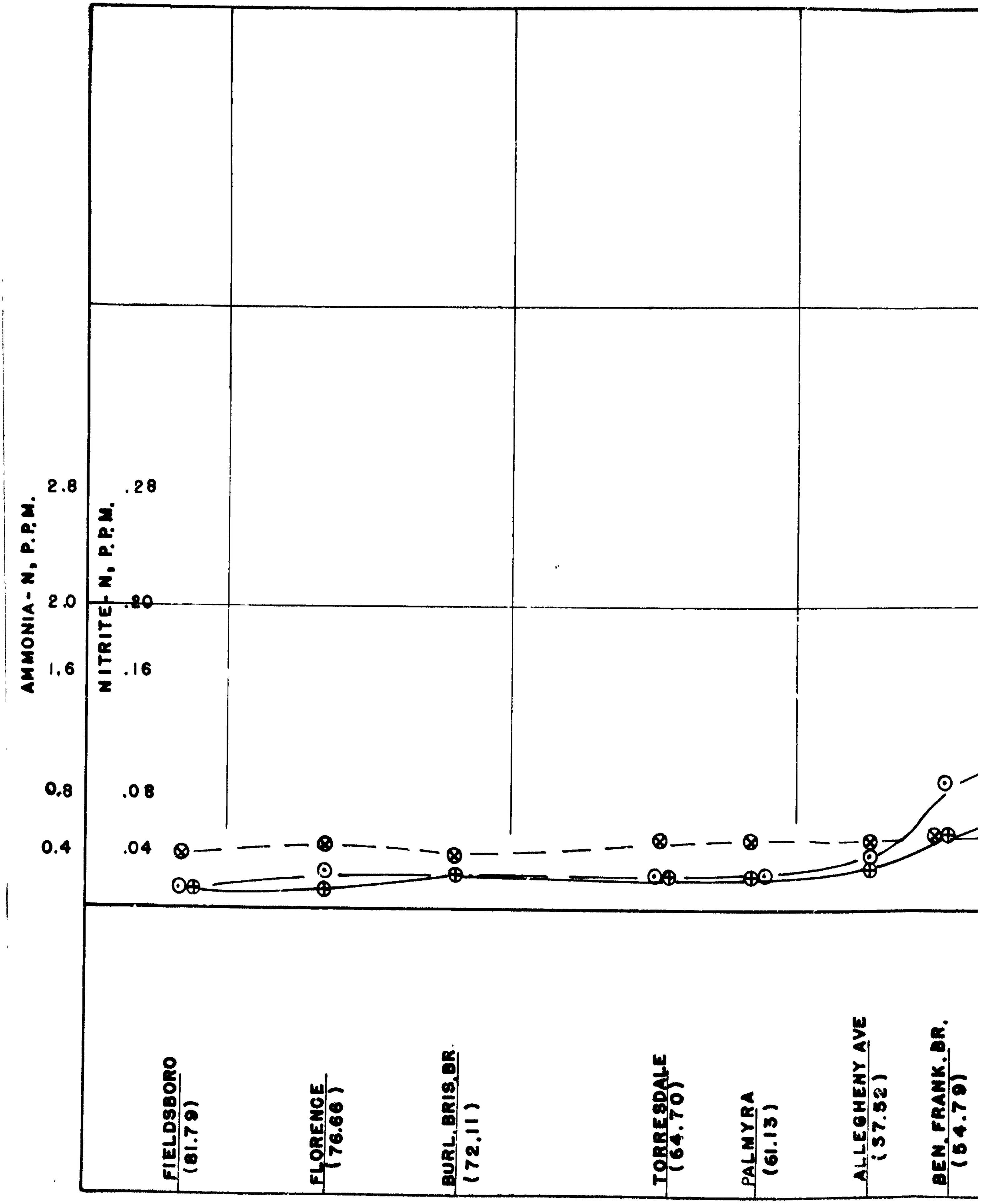



NITRATE-N, P.P.M.
0
FIELDSBORO
(81.79)
FLORENCE
(76.66)
BURL.BRIS.BR.
(72.11)
TORRESDALE
(64.70)
PALMYRA
(61.13)
ALLEGHENY AVE.
(54.79)
BEN.FRANK.BR

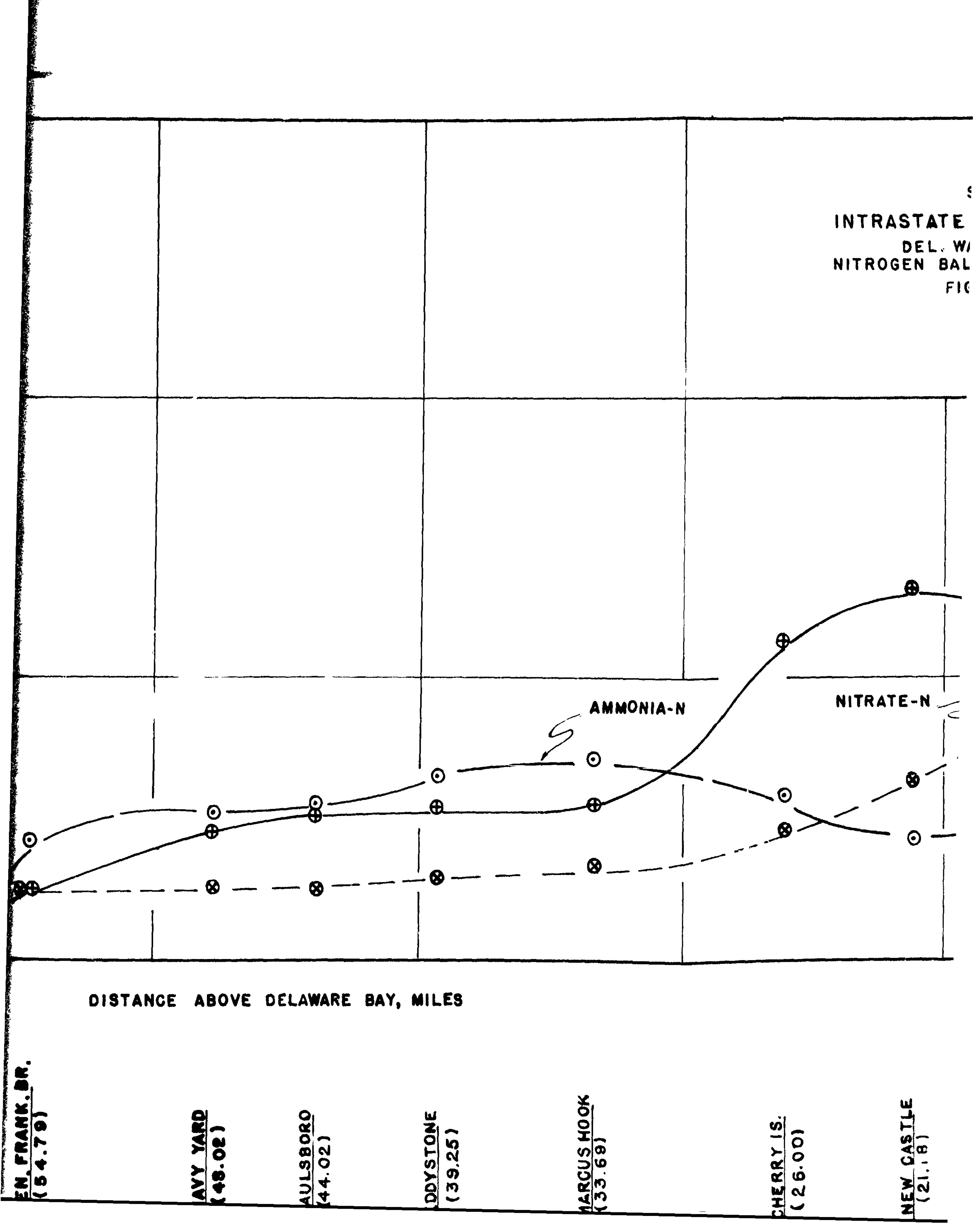

INTRAS
COMPAR
DU
HIGH WATER SLACK
LOW WATER SLACK
DISTANCE ABOVE DELAWARE BAY, MILES
(54.79)
BEN. FRANK. BR (54.79)
NAVY YARD (48.02)
PAULSBORO (44.02)
EDDYSTONE (39.25)
MARCUS HOOK (33.69)
CHERRY IS. (26.00)



STATE OF DELAWARE
INTRASTATE WATER RESOURCE SURVEY
DEL. WATER POLLUTION COMM.
COMPARISON OF NITRATE-NITROGEN CONTENT
DURING HIGH AND LOW WATER SLACK
SEPTEMBER 15, 1958
FIG. 8



AMMONIA-N, P.P.M.
NITRITE-N, P.P.M.
2.8
.28
2.0
.20
1.6
.16
0.8
.08
0.4
.04
FIELDSBORO (81.79)
FLORENCE (76.66)
BURL. BRIS. BR. (72.11)
TORRESDALE (64.70)
PALMYRA (61.13)
ALLEGHENY AVE (57.52)
BEN. FRANK. BR. (54.79)



INTRASTATE
AMMONIA-N
NITRATE-N
DISTANCE ABOVE DELAWARE BAY, MILES
(54.79)
(48.02)
(44.02)
(39.25)
(33.69)
CHERRY IS.
(26.00)
NEW CASTLE
(21.18)

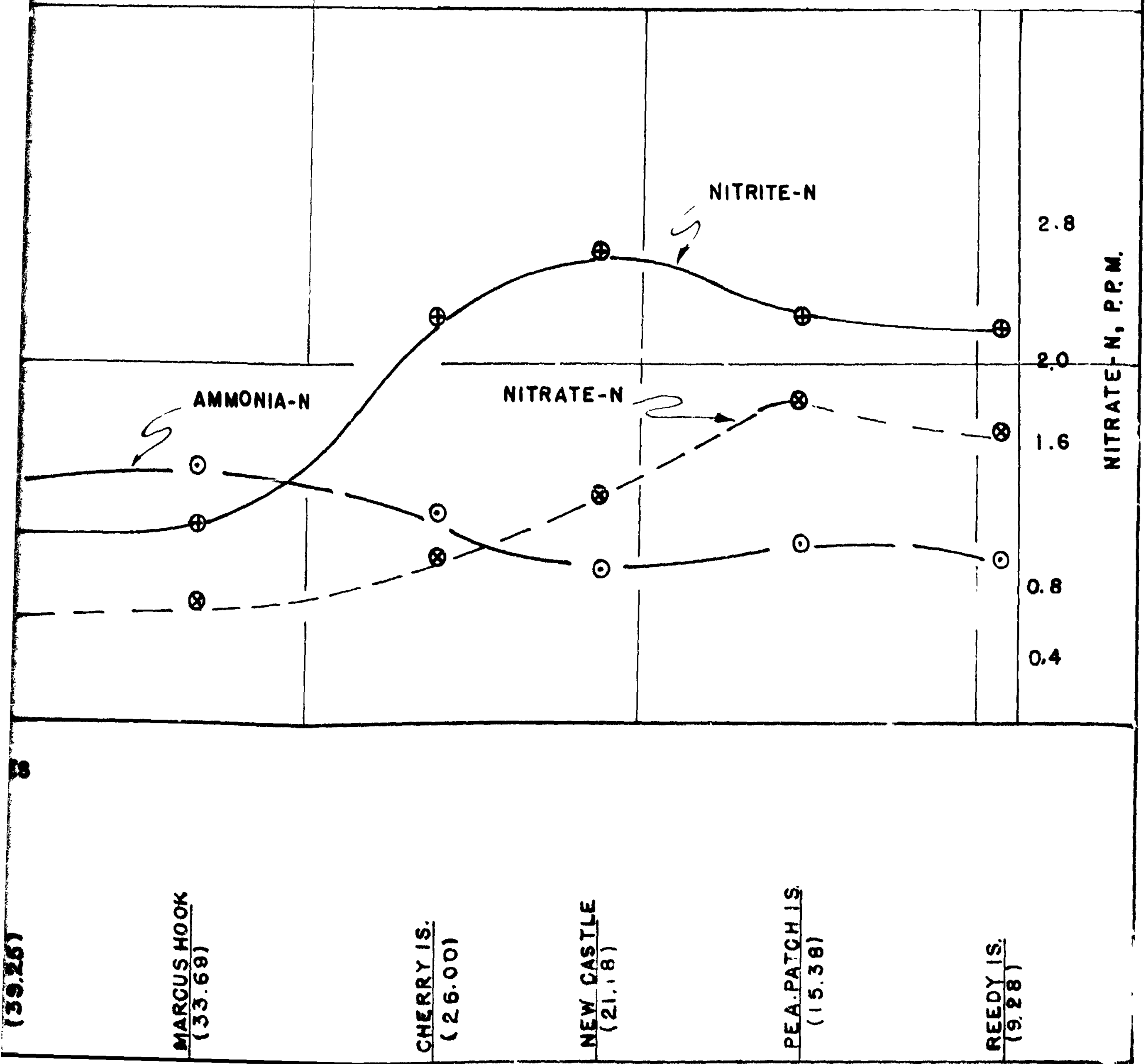
STATE OF DELAWARE

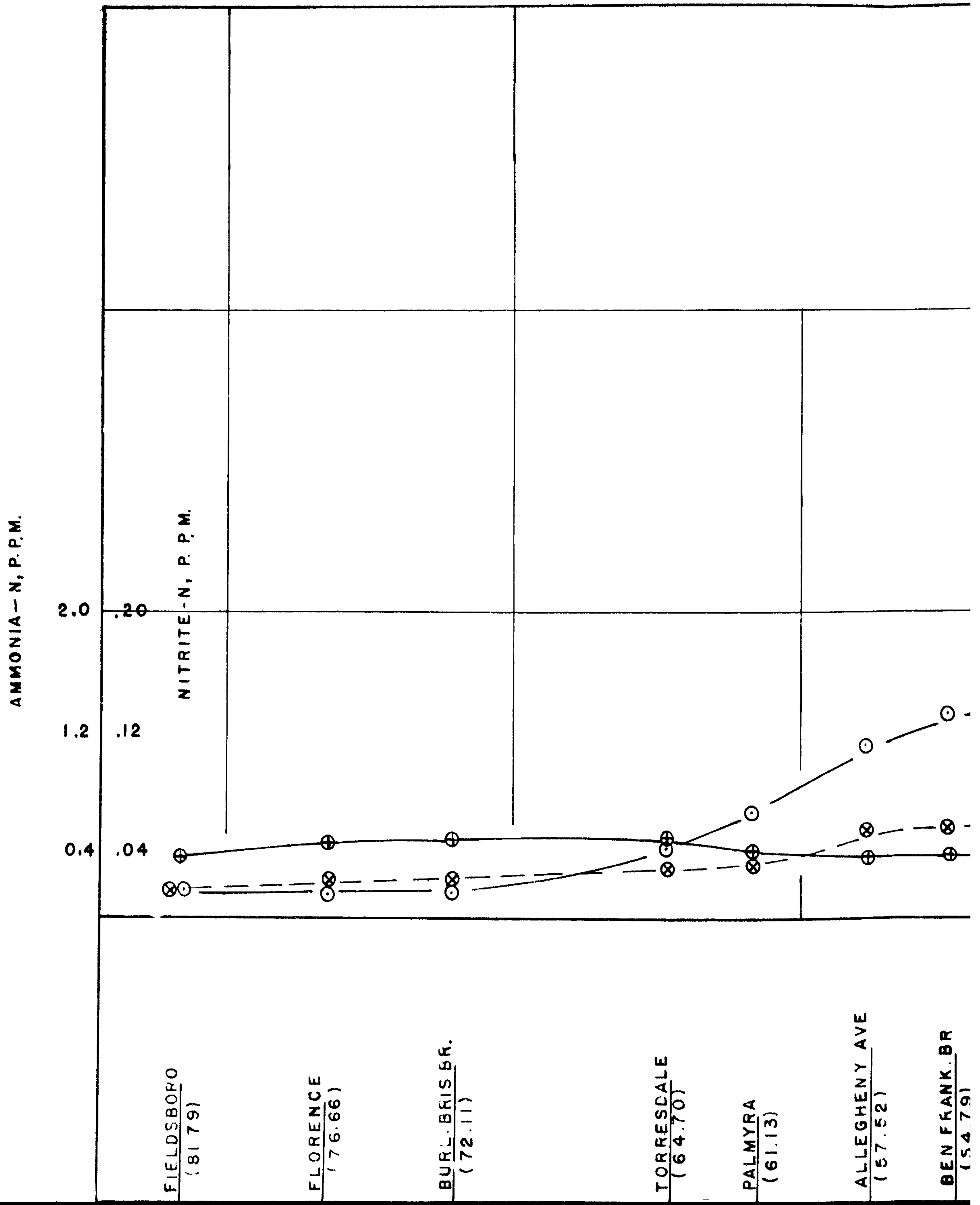
INTRASTATE WATER RESOURCES SURVEY

DEL. WATER POLLUTION COMM.

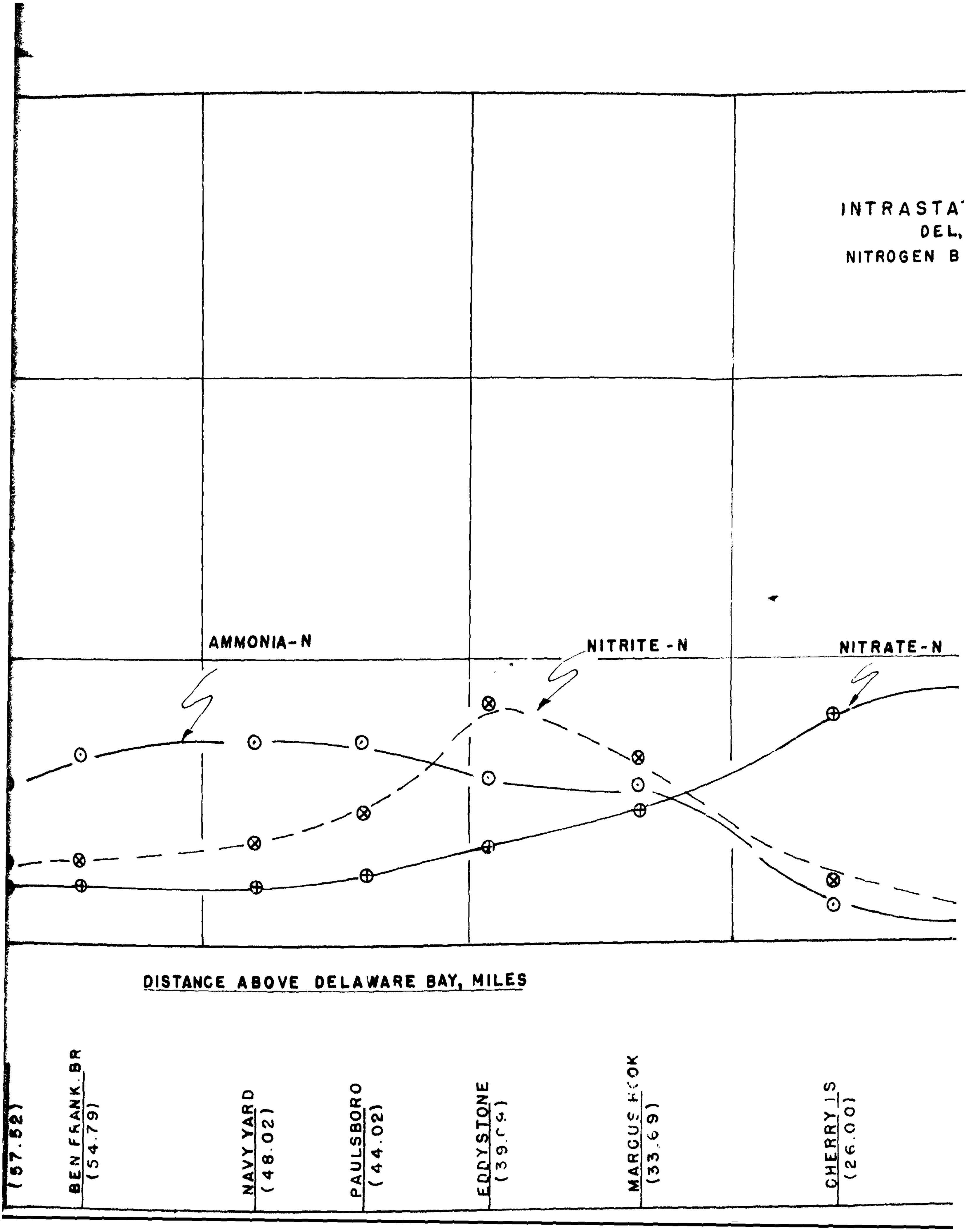
NITROGEN BALANCE DURING LOW WATER SLACK

FIG. 9 JUNE 4, 1957





AMMONIA—N, P.P.M.
NITRITE-N, P. P. M.
2.0
.20
1.2
.12
0.4
.04
FIELDSBORO
(81.79)
FLORENCE
(76.66)
BURL.-BRIS.BR.
(72.11)
TORRESDALE
(64.70)
PALMYRA
(61.13)
ALLEGHENY AVE
(57.52)
BEN FRANK. BR
(54.79)


INTRASTA
DEL,
NITROGEN B
AMMONIA-N
NITRITE-N
NITRATE-N
DISTANCE ABOVE DELAWARE BAY, MILES
(57.52)
BEN FRANK. BR
(54.79)
NAVY YARD
(48.02)
PAULSBORO
(44.02)
EDDYSTONE
MARCUS
(33.69)
CHERRY IS
(26.00)

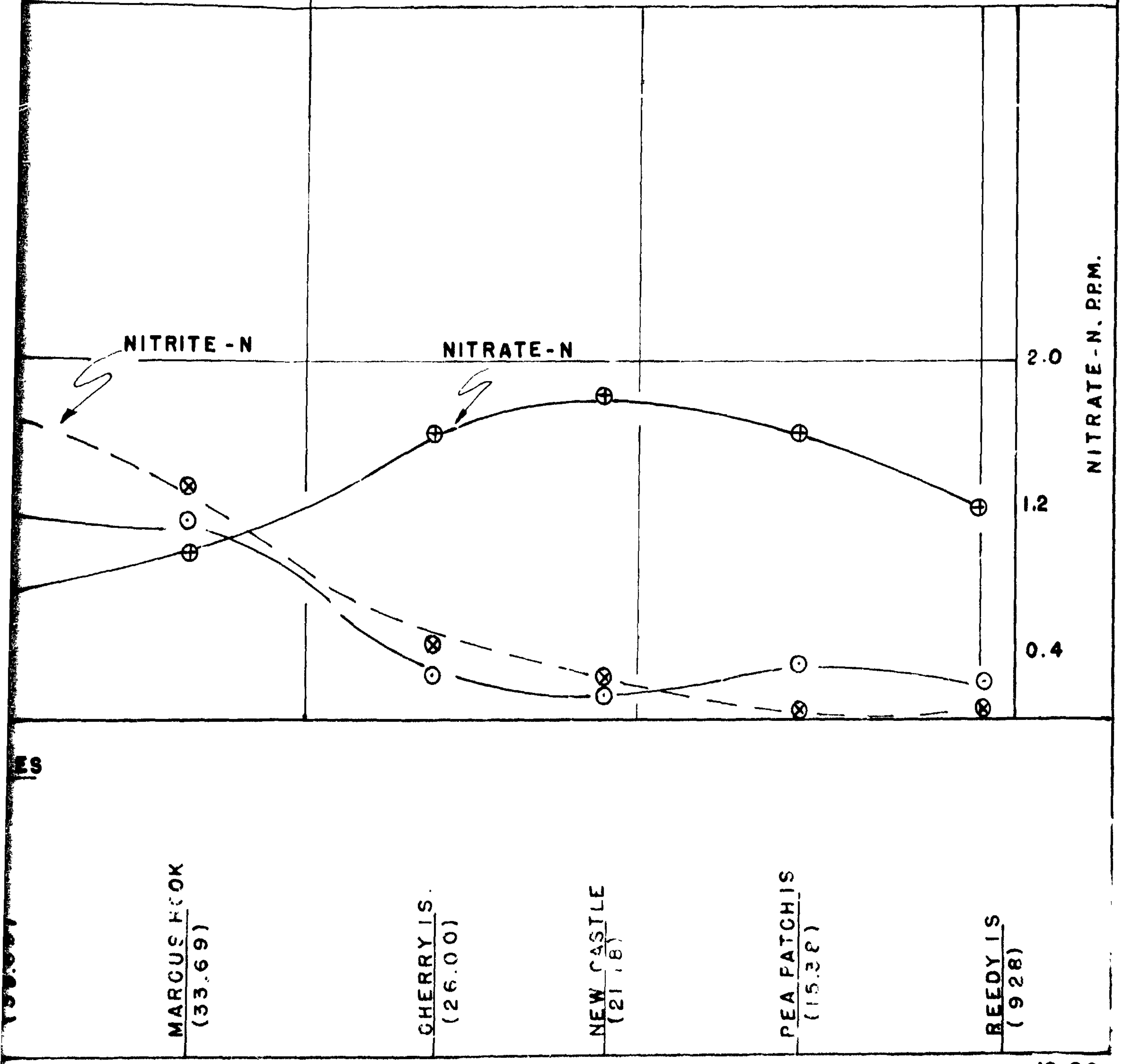
STATE OF DELAWARE

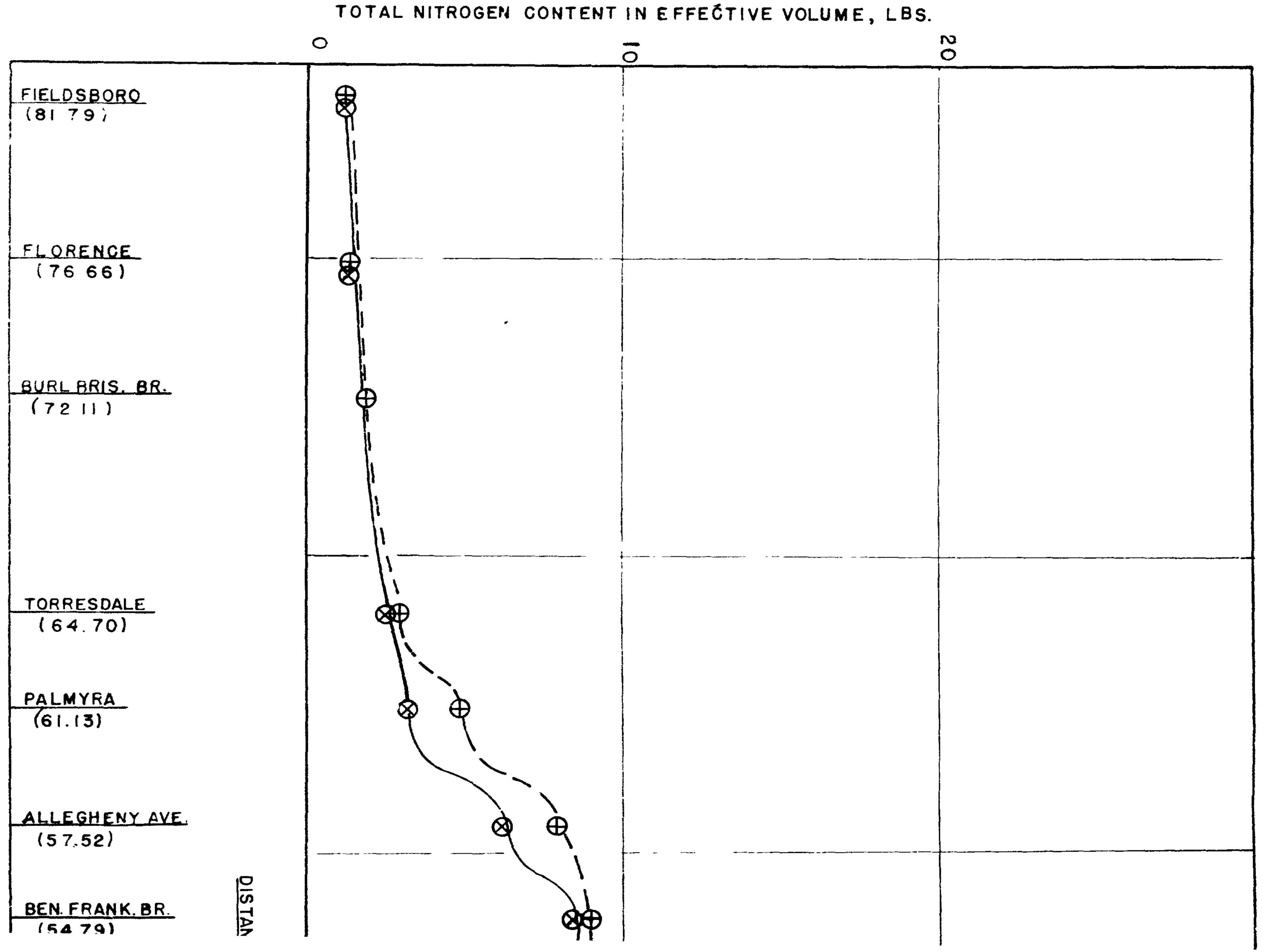
INTRASTATE WATER RESOURCES SURVEY

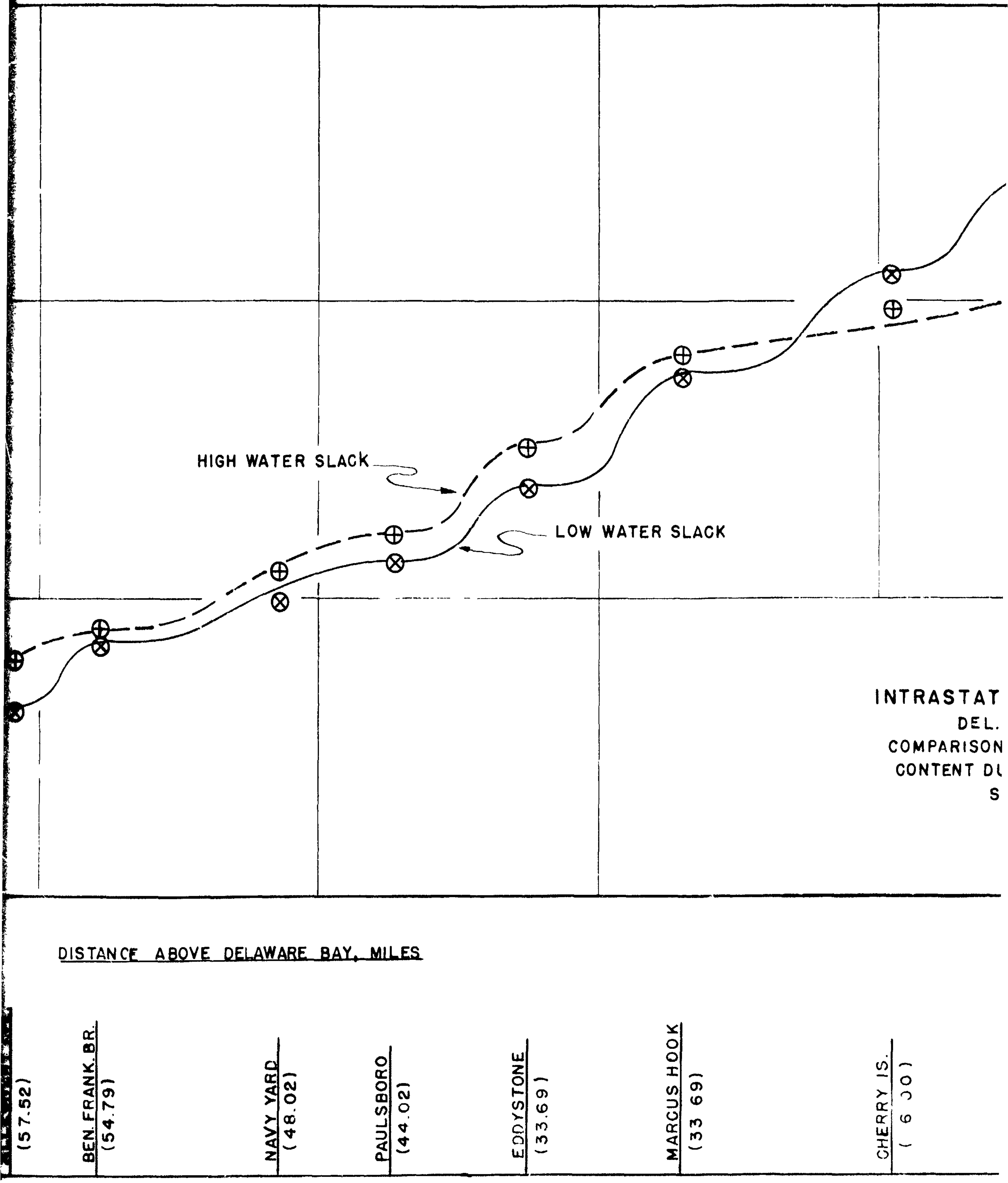
DEL. WATER POLLUTION COMM.

NITROGEN BALANCE DURING HIGH WATER SLACK

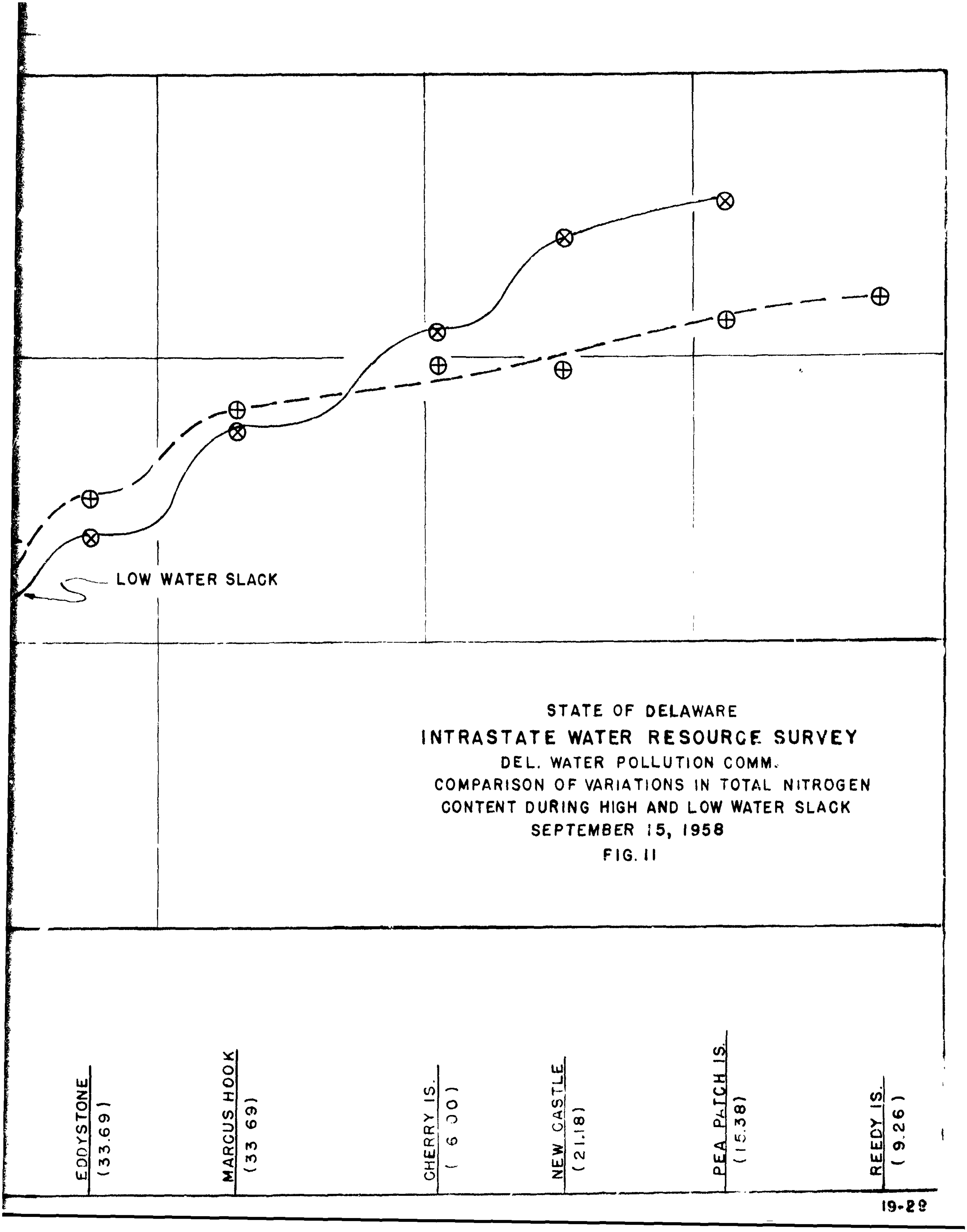
FIG. 10 JUNE 10, 1957



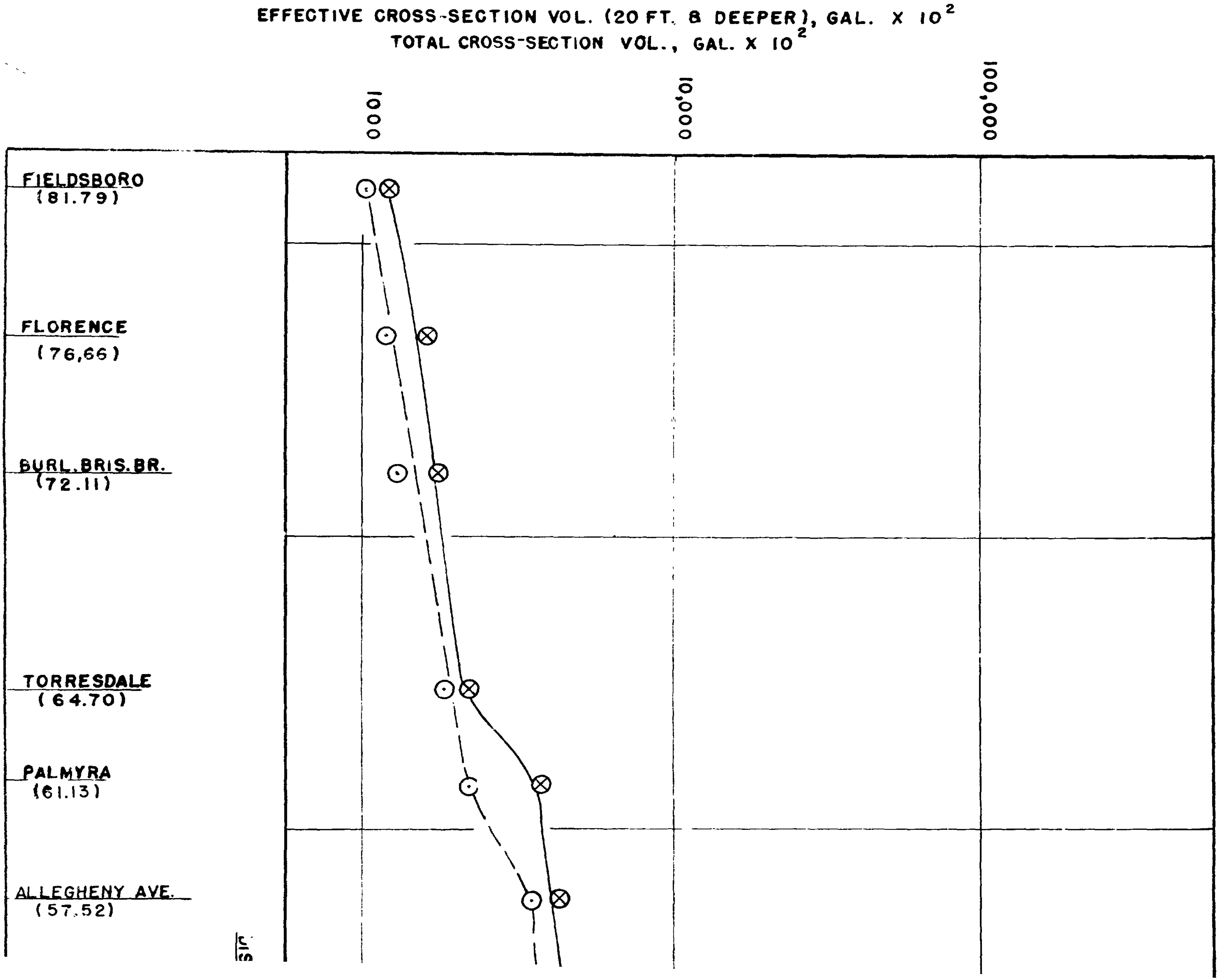

TOTAL NITROGEN CONTENT IN EFFECTIVE VOLUME, LBS.
0
10
20
FIELDSBORO (81.79)
FLORENCE (76.66)
BURL.BRIS. BR. (72.11)
TORRESDALE (64.70)
PALMYRA (61.13)
ALLEGHENY AVE. (57.52)
BEN. FRANK. BR. (54.79)

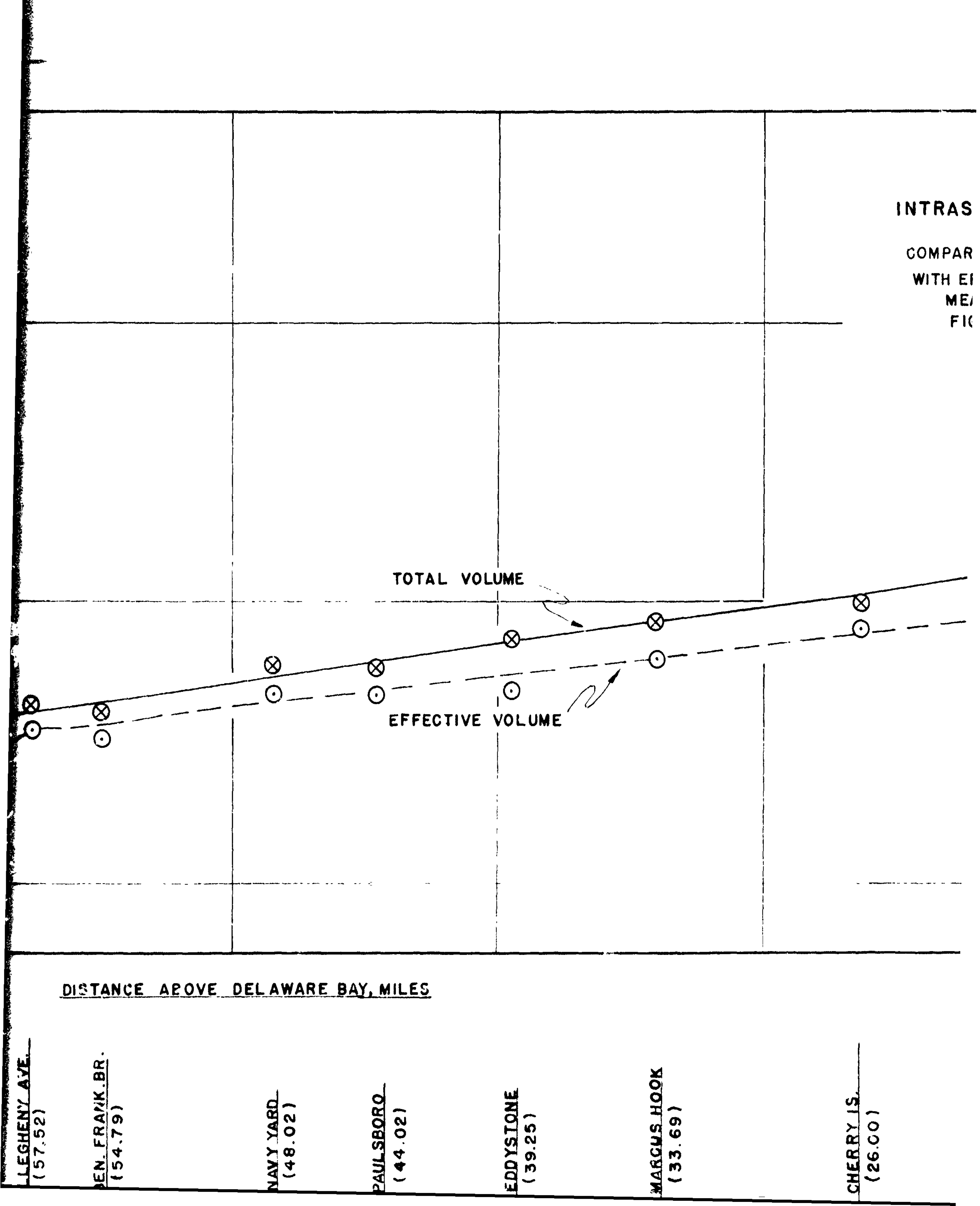


HIGH WATER SLACK
LOW WATER SLACK
INTRASTAT
DEL.
COMPARISON
CONTENT DU
S
DISTANCE ABOVE DELAWARE BAY, MILES
(57.52)
BEN. FRANK. BR. (54.79)
NAVY YARD (48.02)
PAULSBORO (44.02)
EDDYSTONE (33.69)
MARCUS HOOK (33 69)
CHERRY IS.

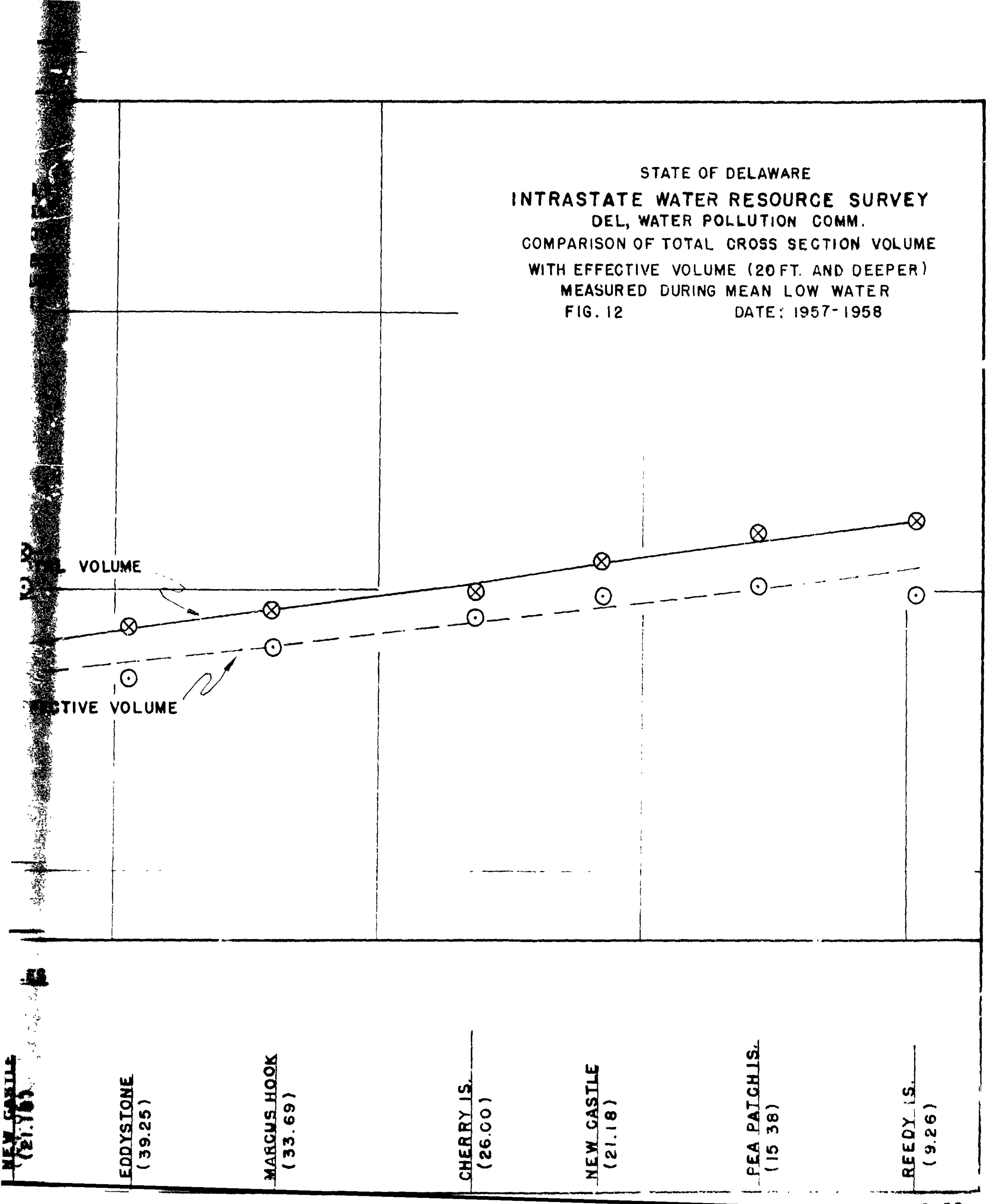


STATE OF DELAWARE
INTRASTATE WATER RESOURCE SURVEY
DEL. WATER POLLUTION COMM.
COMPARISON OF VARIATIONS IN TOTAL NITROGEN CONTENT DURING HIGH AND LOW WATER SLACK
SEPTEMBER 15, 1958
FIG. 11

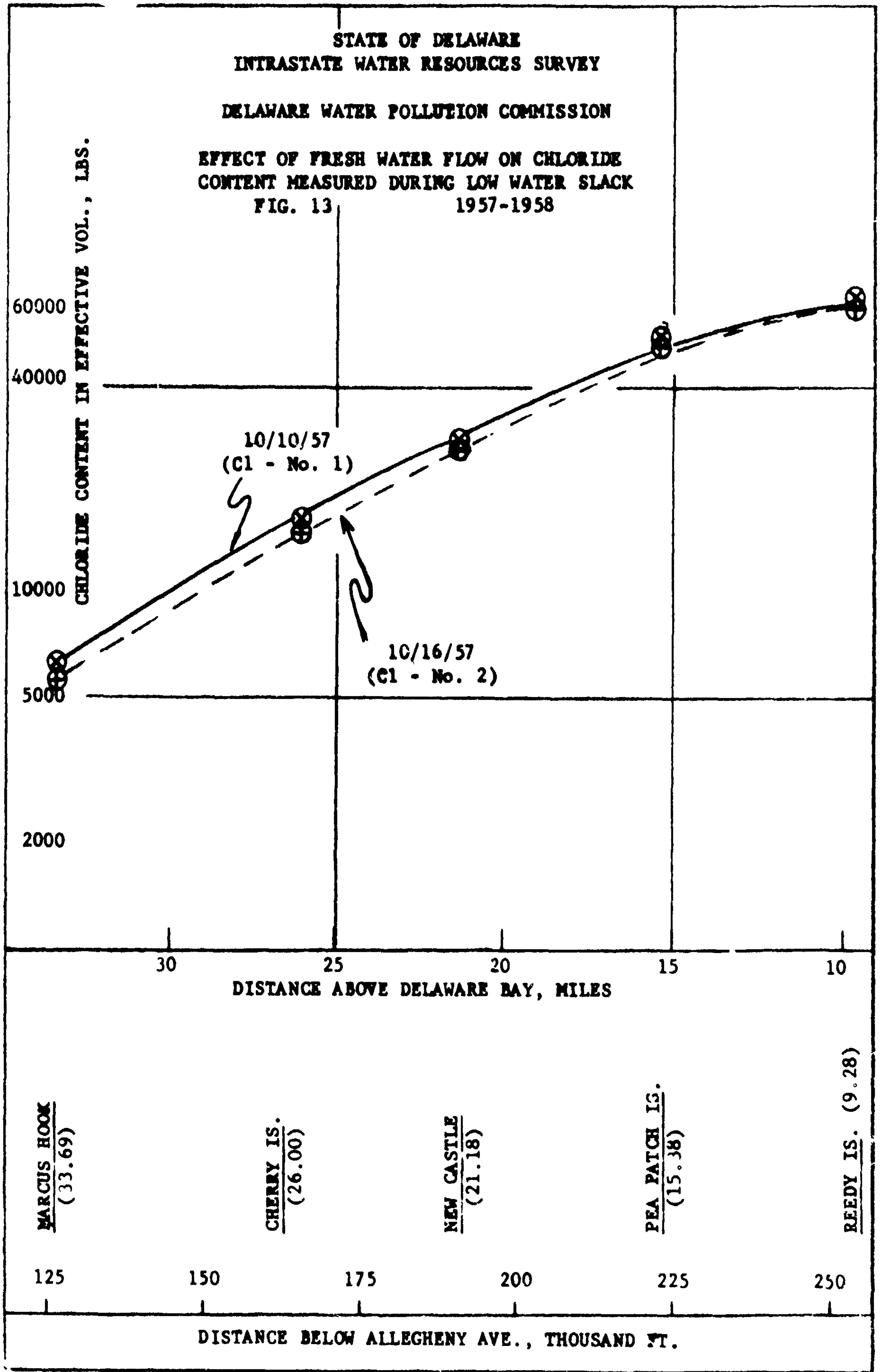

EFFECTIVE CROSS-SECTION VOL. (20 FT. & DEEPER), GAL. X 10²
TOTAL CROSS-SECTION VOL., GAL. X 10²
1000
10,000
100,000
FIELDSBORO (81.79)
FLORENCE (76,66)
BURL.BRIS.BR. (72.11)
TORRESDALE (64.70)
PALMYRA (61.13)
ALLEGHENY AVE. (57.52)

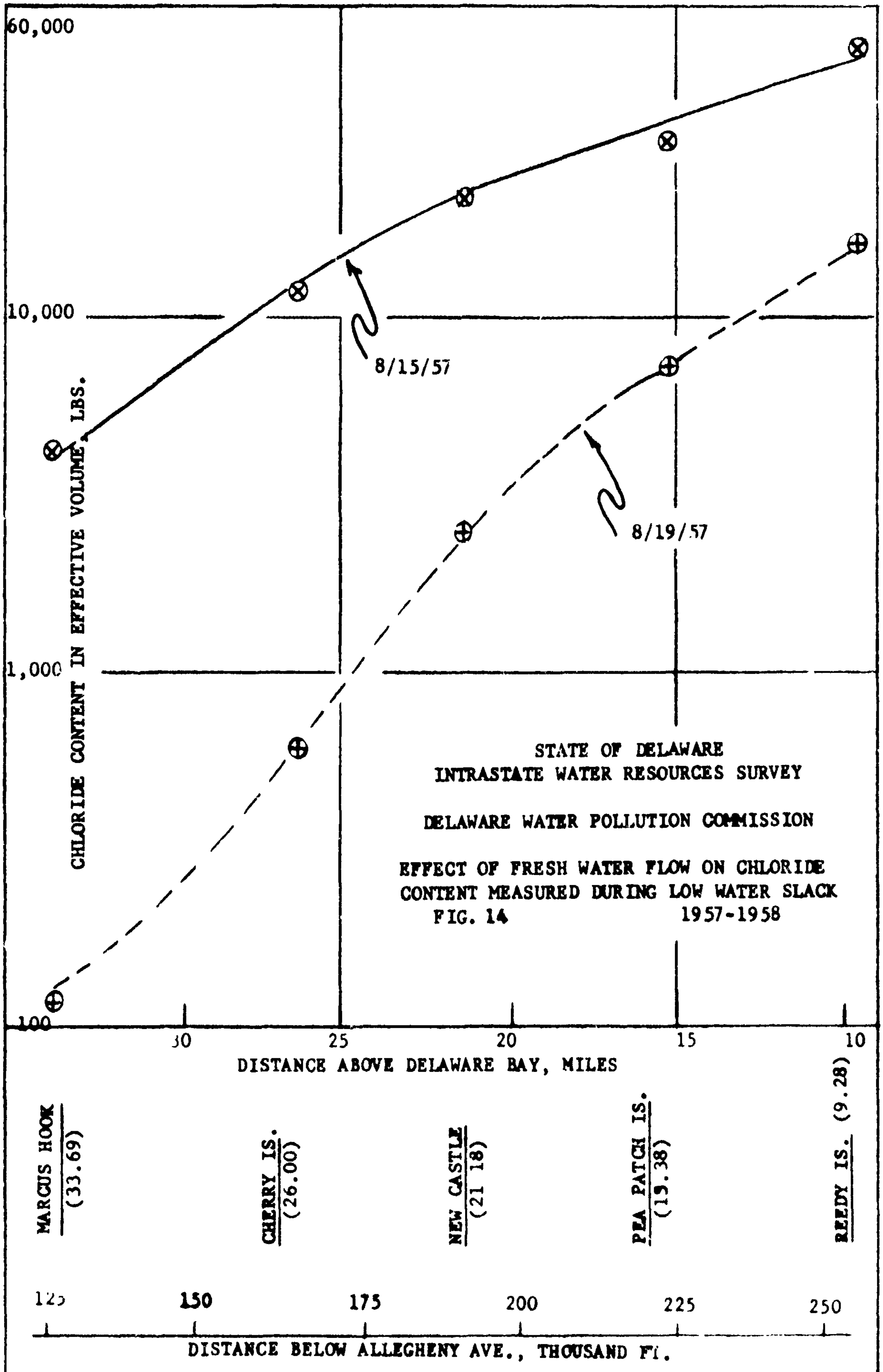


INTRAS
COMPAR
WITH EF
MEA
FIG
TOTAL VOLUME
EFFECTIVE VOLUME
DISTANCE ABOVE DELAWARE BAY, MILES
LEGHENY AVE. (57.52)
BEN. FRANK. BR. (54.79)
NAVY YARD (48.02)
PAULSBORO (44.02)
EDDYSTONE (39.25)
MARCUS HOOK (33.69)
CHERRY IS. (26.00)



STATE OF DELAWARE
INTRASTATE WATER RESOURCE SURVEY
DEL, WATER POLLUTION COMM.
COMPARISON OF TOTAL CROSS SECTION VOLUME
WITH EFFECTIVE VOLUME (20 FT. AND DEEPER)
MEASURED DURING MEAN LOW WATER
FIG. 12 DATE: 1957-1958
VOLUME
TIVE VOLUME
EDDYSTONE (39.25)
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.26)

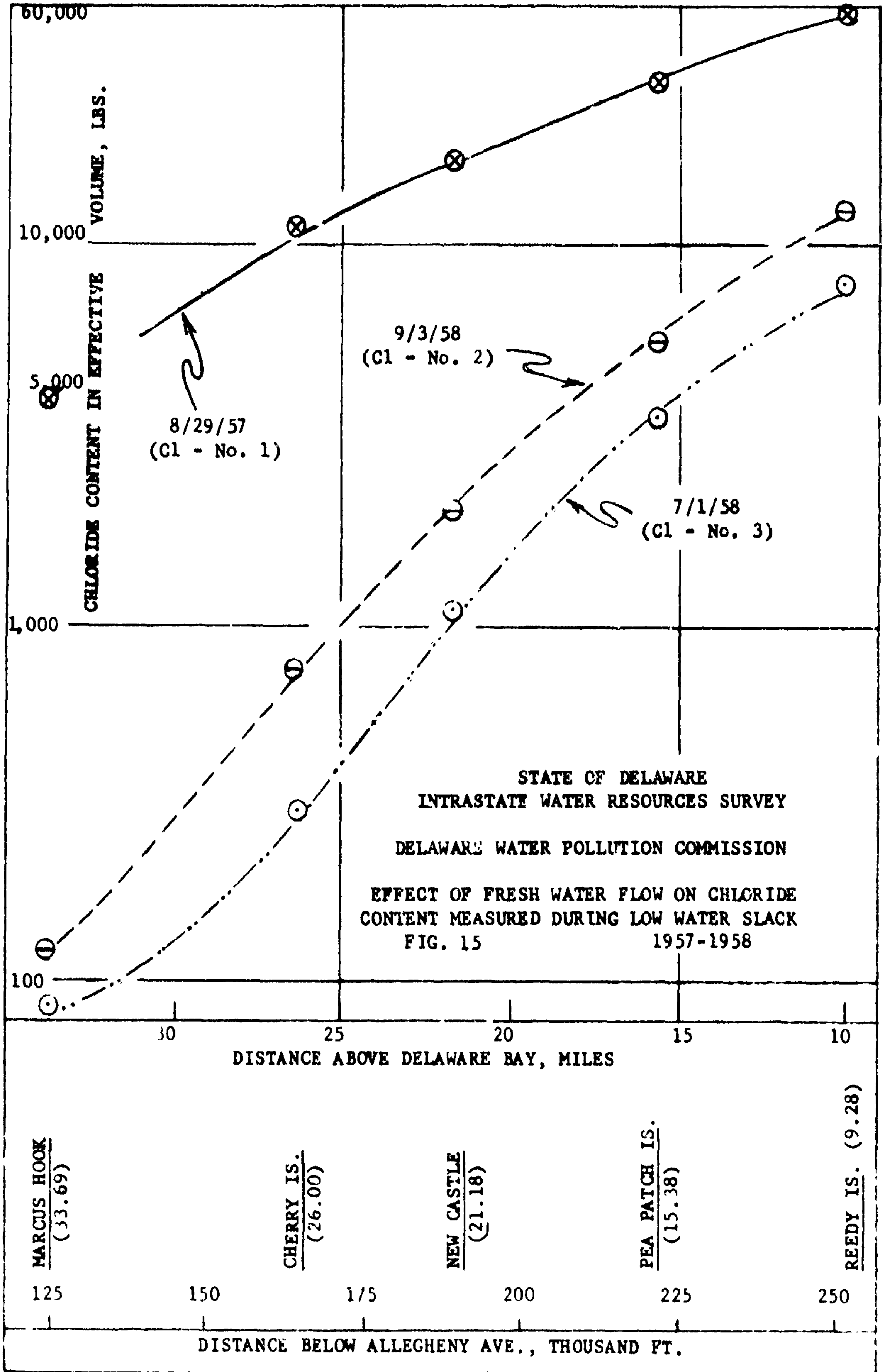

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON CHLORIDE CONTENT MEASURED DURING LOW WATER SLACK
FIG. 13 1957-1958
CHLORIDE CONTENT IN EFFECTIVE VOL., LBS.
60000
40000
10000
5000
2000
10/10/57
(Cl - No. 1)
10/16/57
(Cl - No. 2)
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

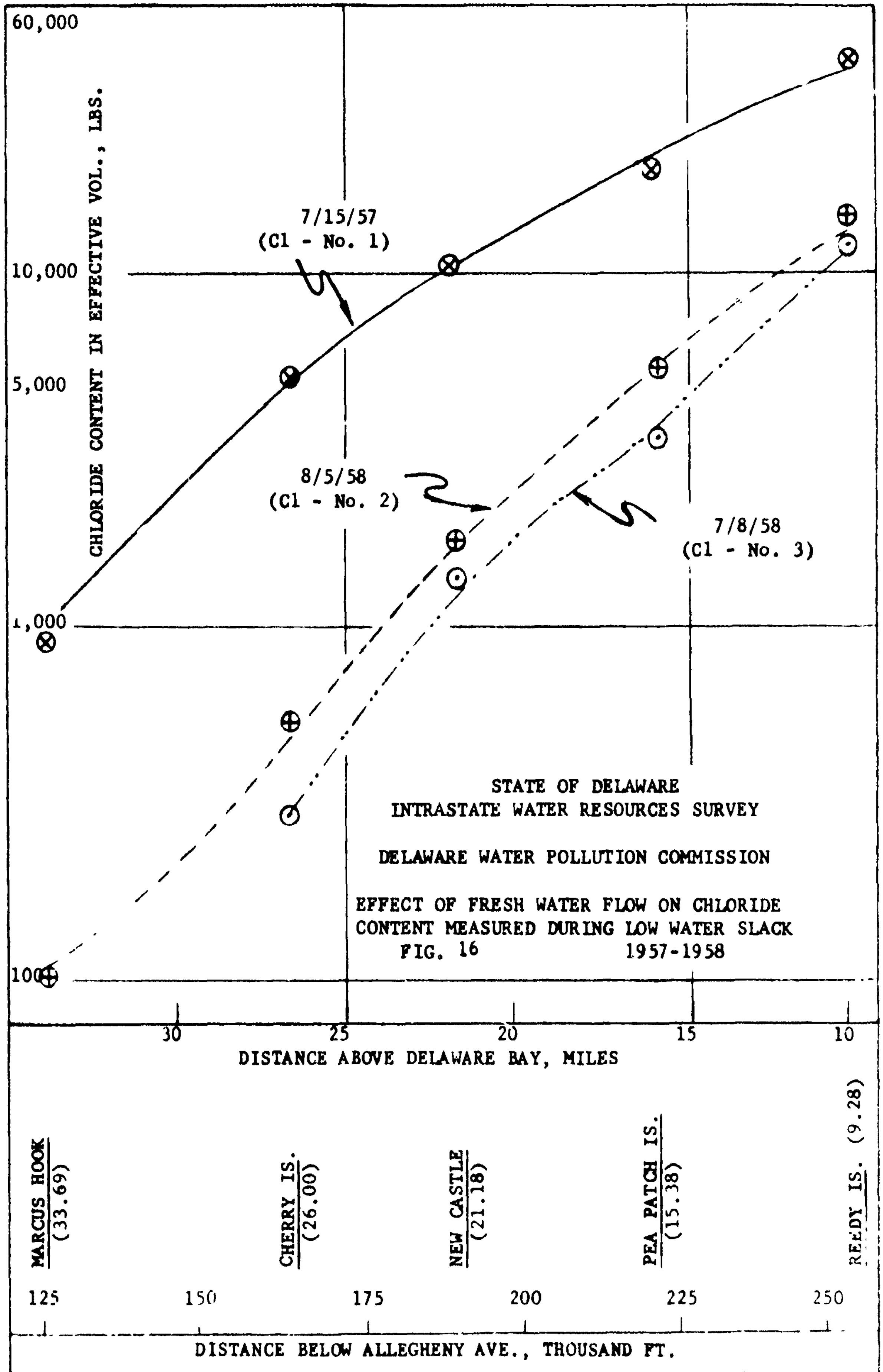
EFFECT OF FRESH WATER FLOW ON CHLORIDE CONTENT MEASURED DURING LOW WATER SLACK
FIG. 14 1957-1958

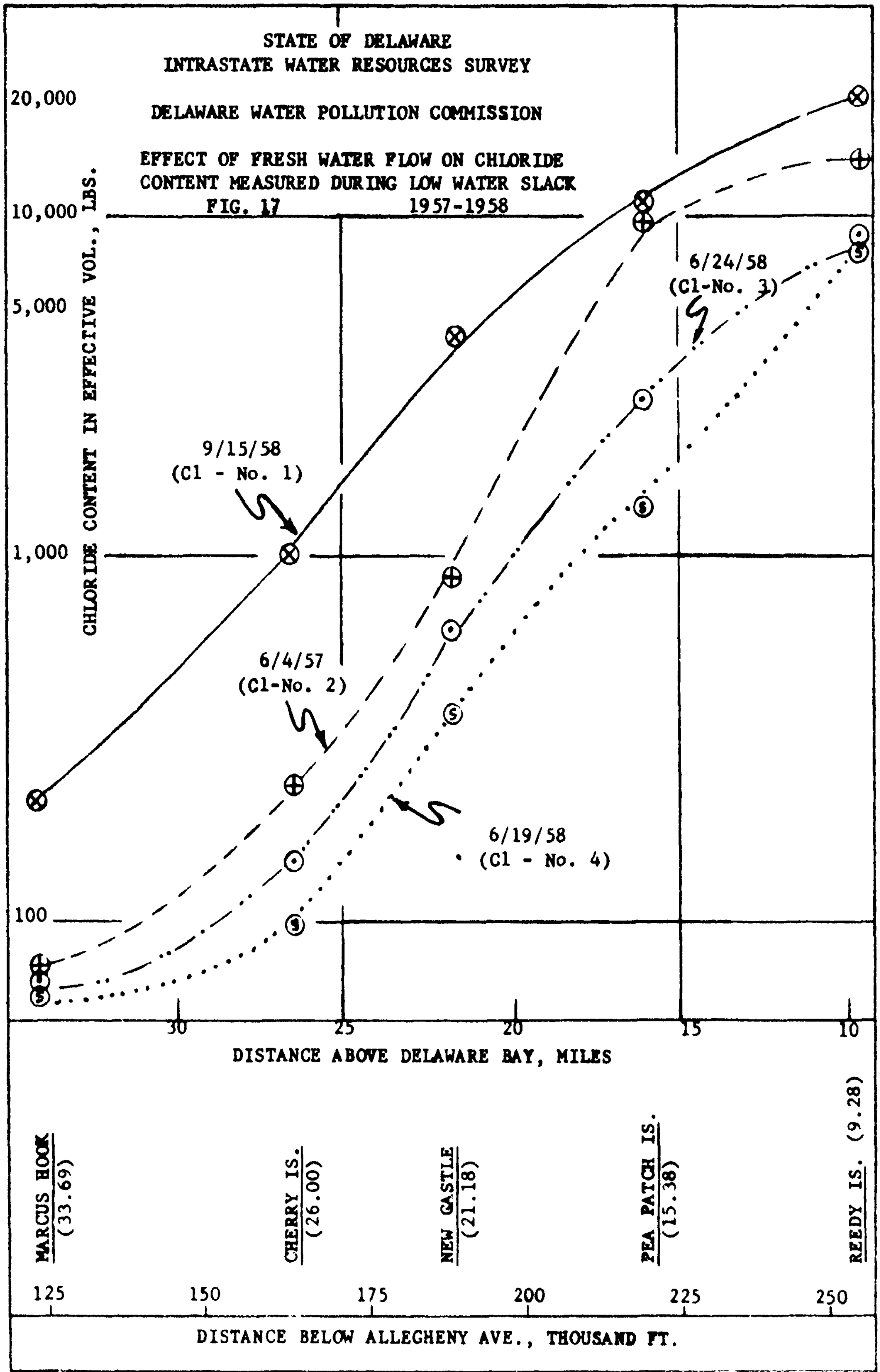


STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

EFFECT OF FRESH WATER FLOW ON CHLORIDE
CONTENT MEASURED DURING LOW WATER SLACK
FIG. 15 1957-1958

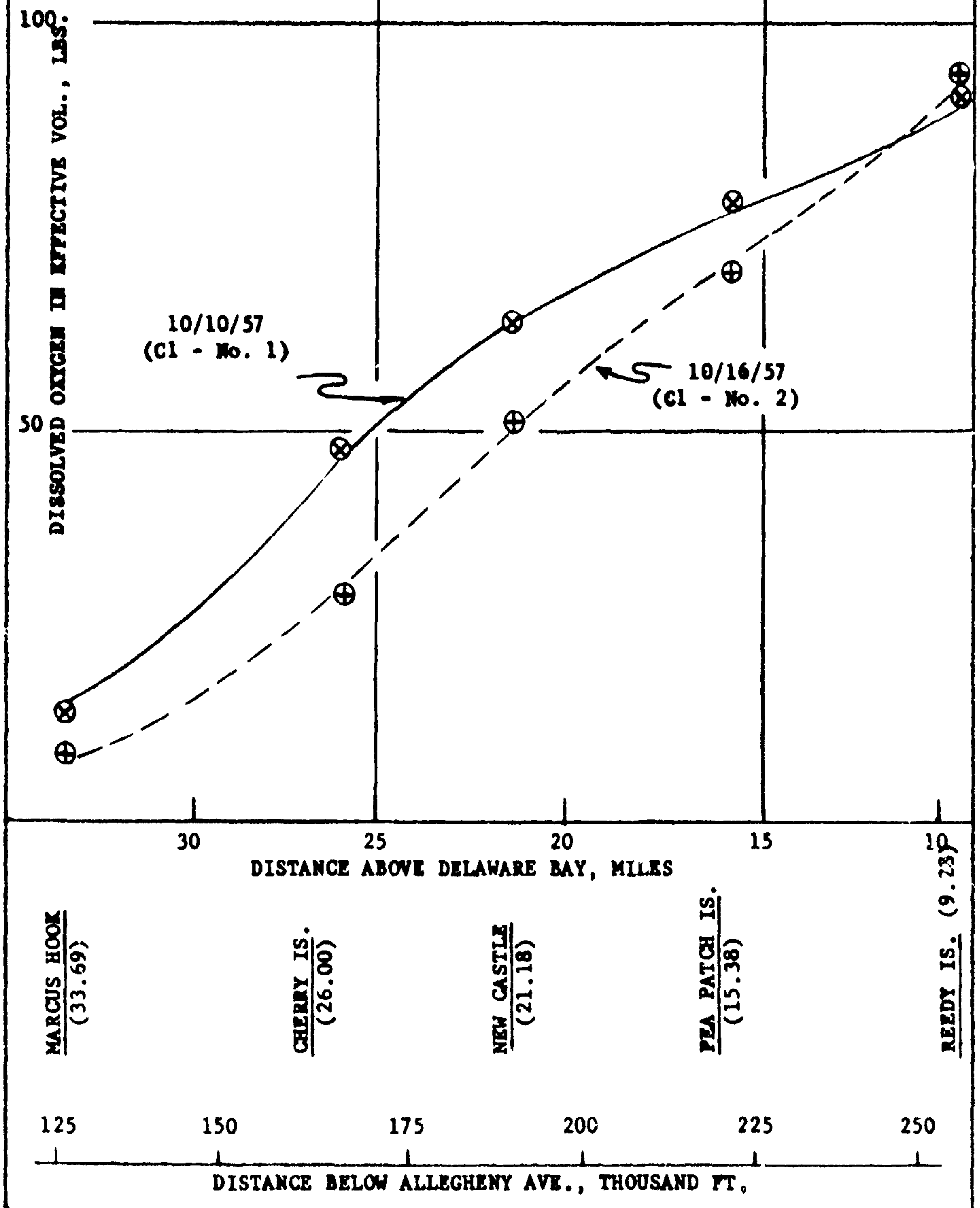

60,000
10,000
5,000
1,000
100
CHLORIDE CONTENT IN EFFECTIVE VOL., LBS.
7/15/57
(Cl - No. 1)
8/5/58
(Cl - No. 2)
7/8/58
(Cl - No. 3)
STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON CHLORIDE
CONTENT MEASURED DURING LOW WATER SLACK
FIG. 16 1957-1958
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.

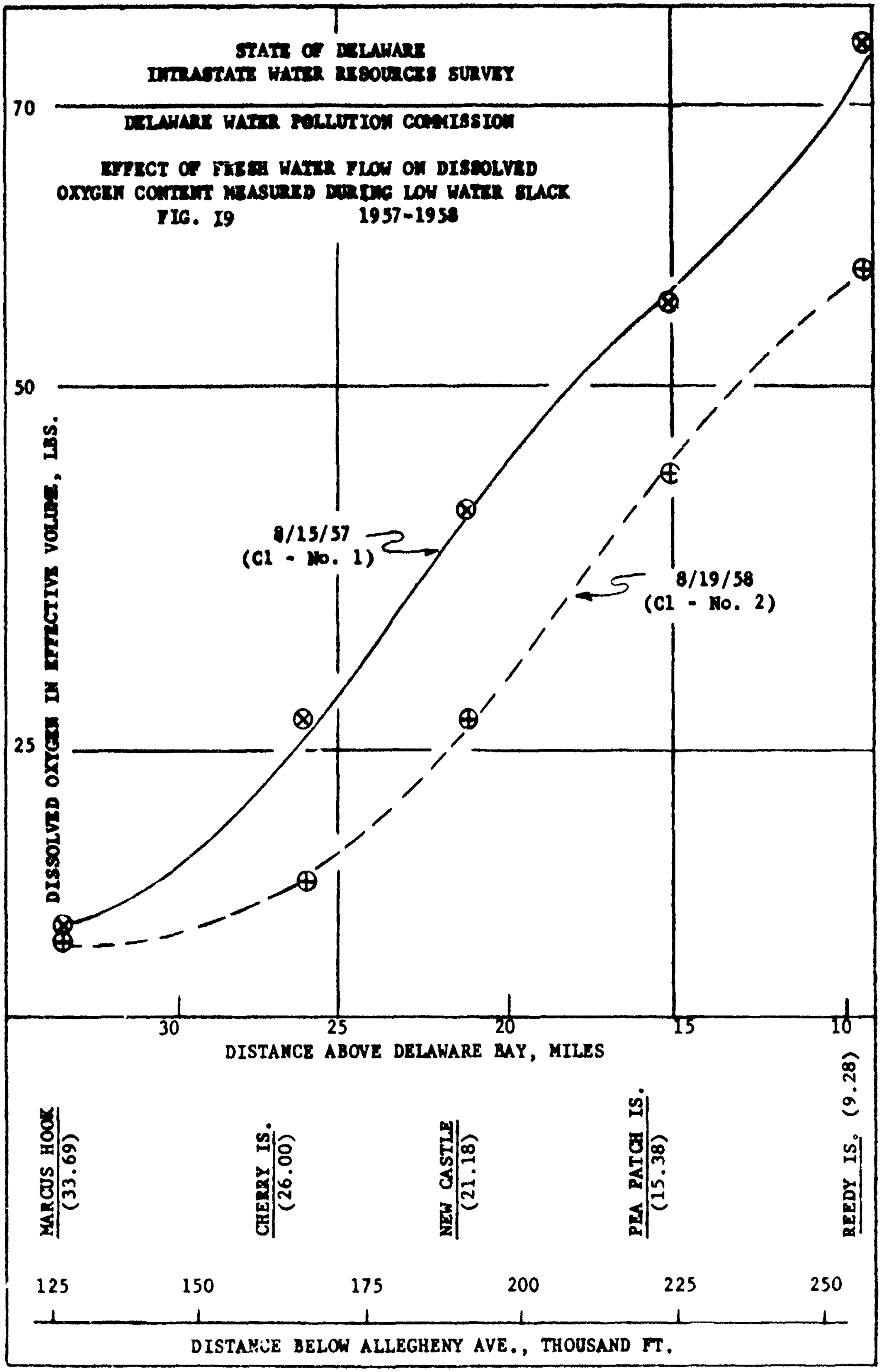

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON CHLORIDE
CONTENT MEASURED DURING LOW WATER SLACK
FIG. 17 1957-1958
20,000
10,000
5,000
1,000
100
CHLORIDE CONTENT IN EFFECTIVE VOL., LBS.
9/15/58
(Cl - No. 1)
6/4/57
(Cl-No. 2)
6/24/58
(Cl-No. 3)
6/19/58
(Cl - No. 4)
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.

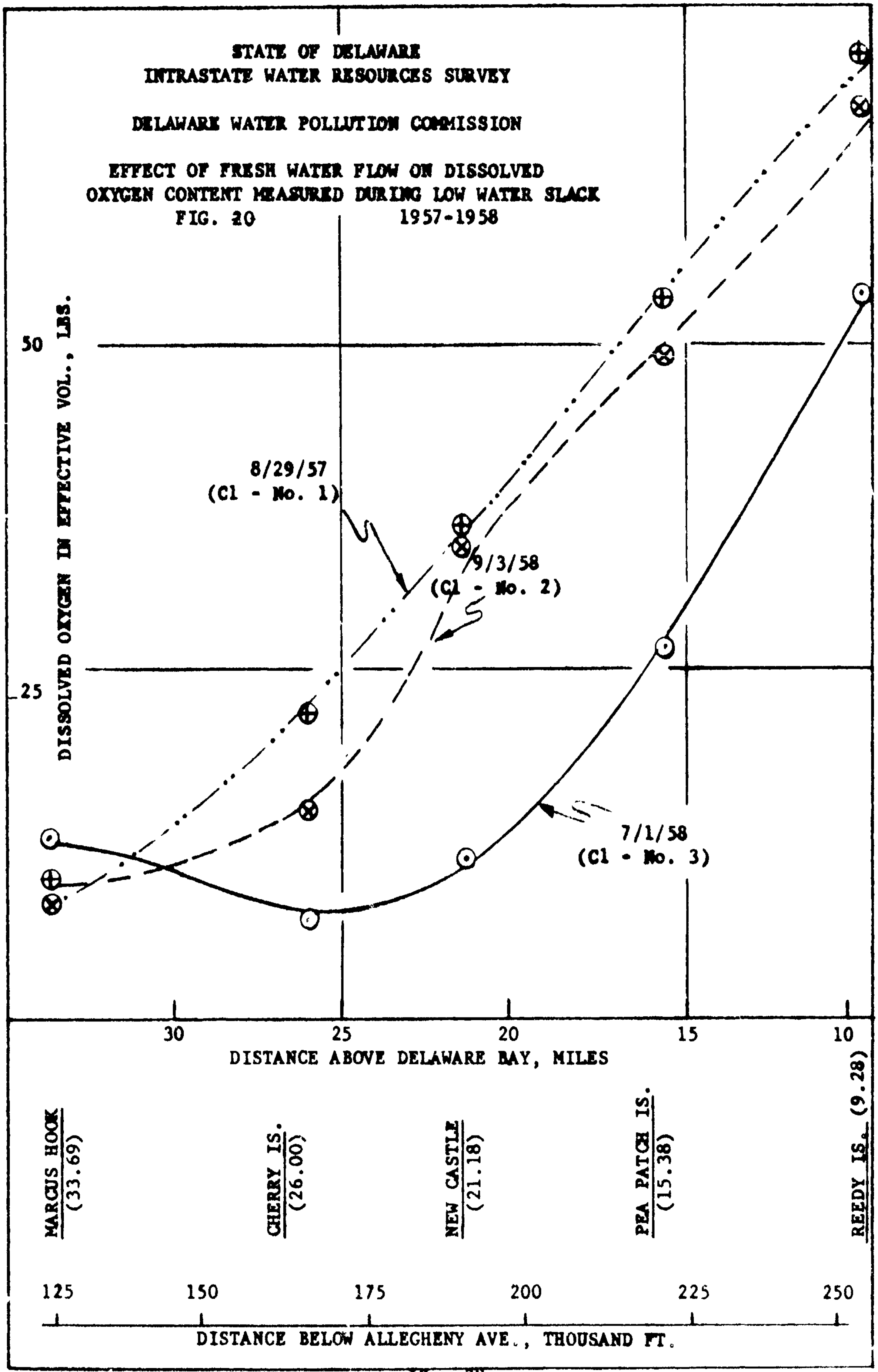
STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

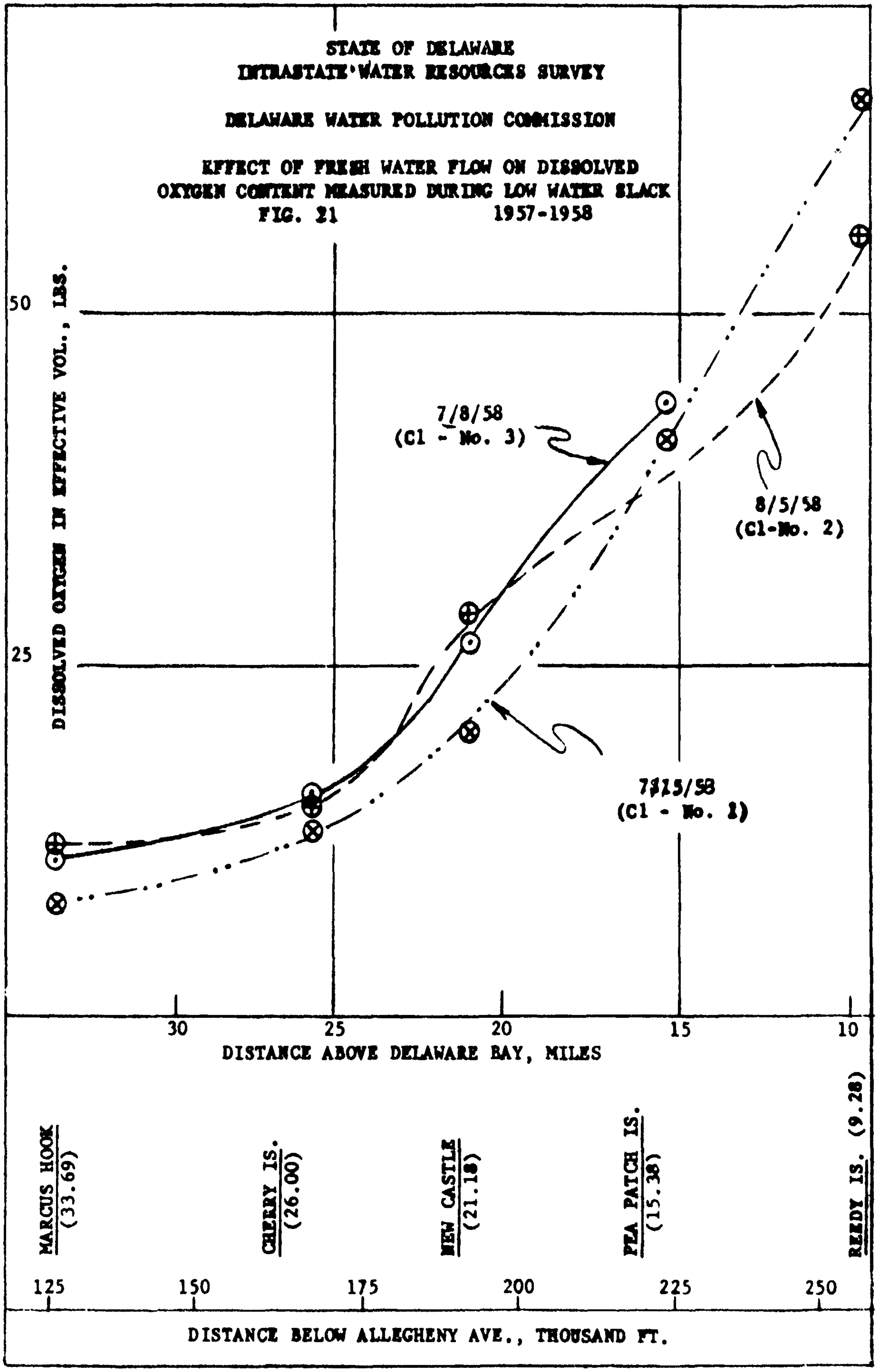
DELAWARE WATER POLLUTION COMMISSION

EFFECT OF FRESH WATER FLOW ON DISSOLVED
OXYGEN CONTENT DURING LOW WATER SLACK
FIG. 18 1957-1958

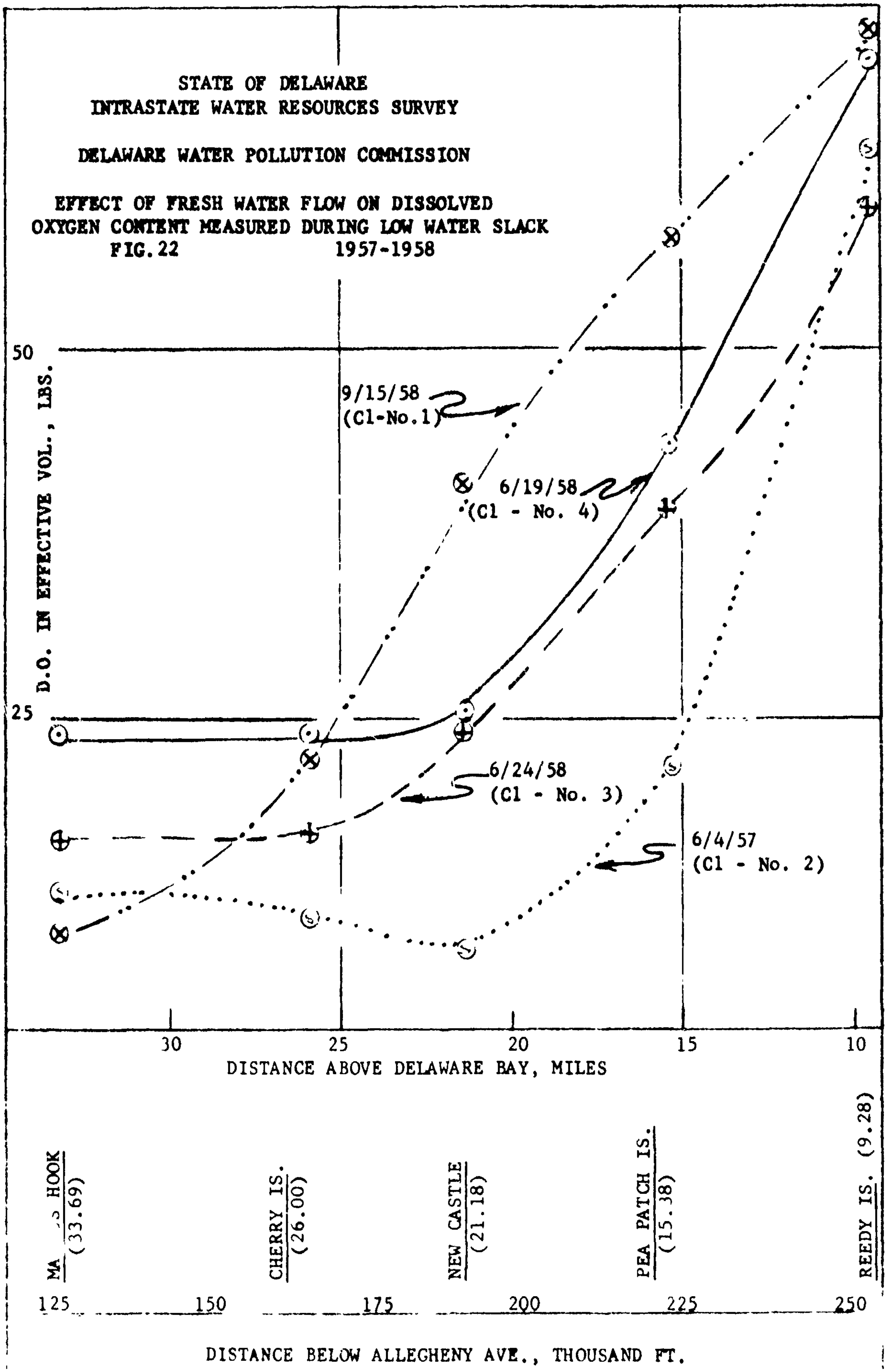



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON DISSOLVED
OXYGEN CONTENT MEASURED DURING LOW WATER SLACK
FIG. 19 1957-1958
70
50
25
DISSOLVED OXYGEN IN EFFECTIVE VOLUME, LBS.
8/15/57
(Cl - No. 1)
8/19/58
(Cl - No. 2)
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.

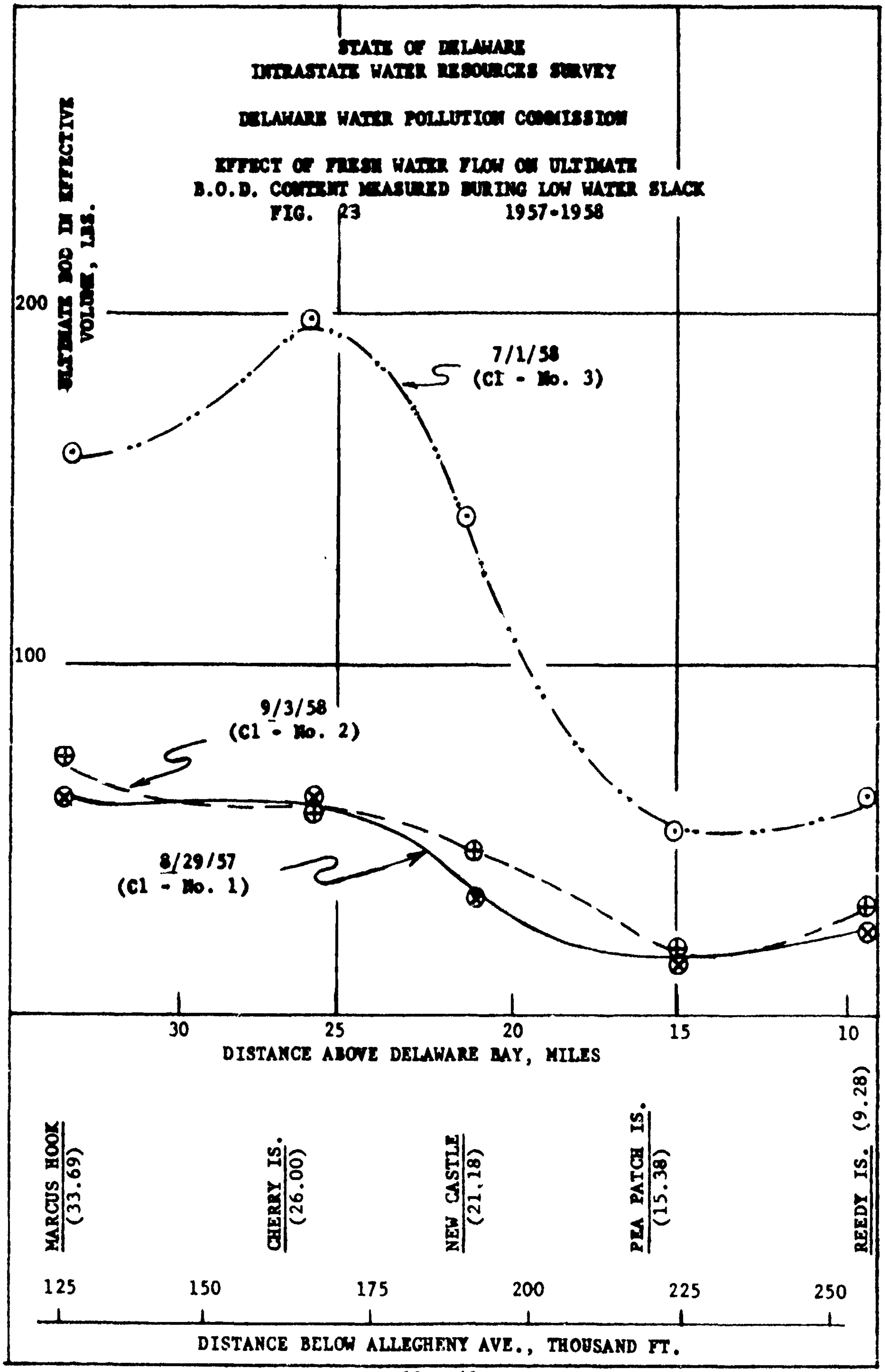

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON DISSOLVED
OXYGEN CONTENT MEASURED DURING LOW WATER SLACK
FIG. 20
1957-1958
DISSOLVED OXYGEN IN EFFECTIVE VOL., LBS.
50
25
8/29/57
(Cl - No. 1)
9/3/58
(Cl - No. 2)
7/1/58
(Cl - No. 3)
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.

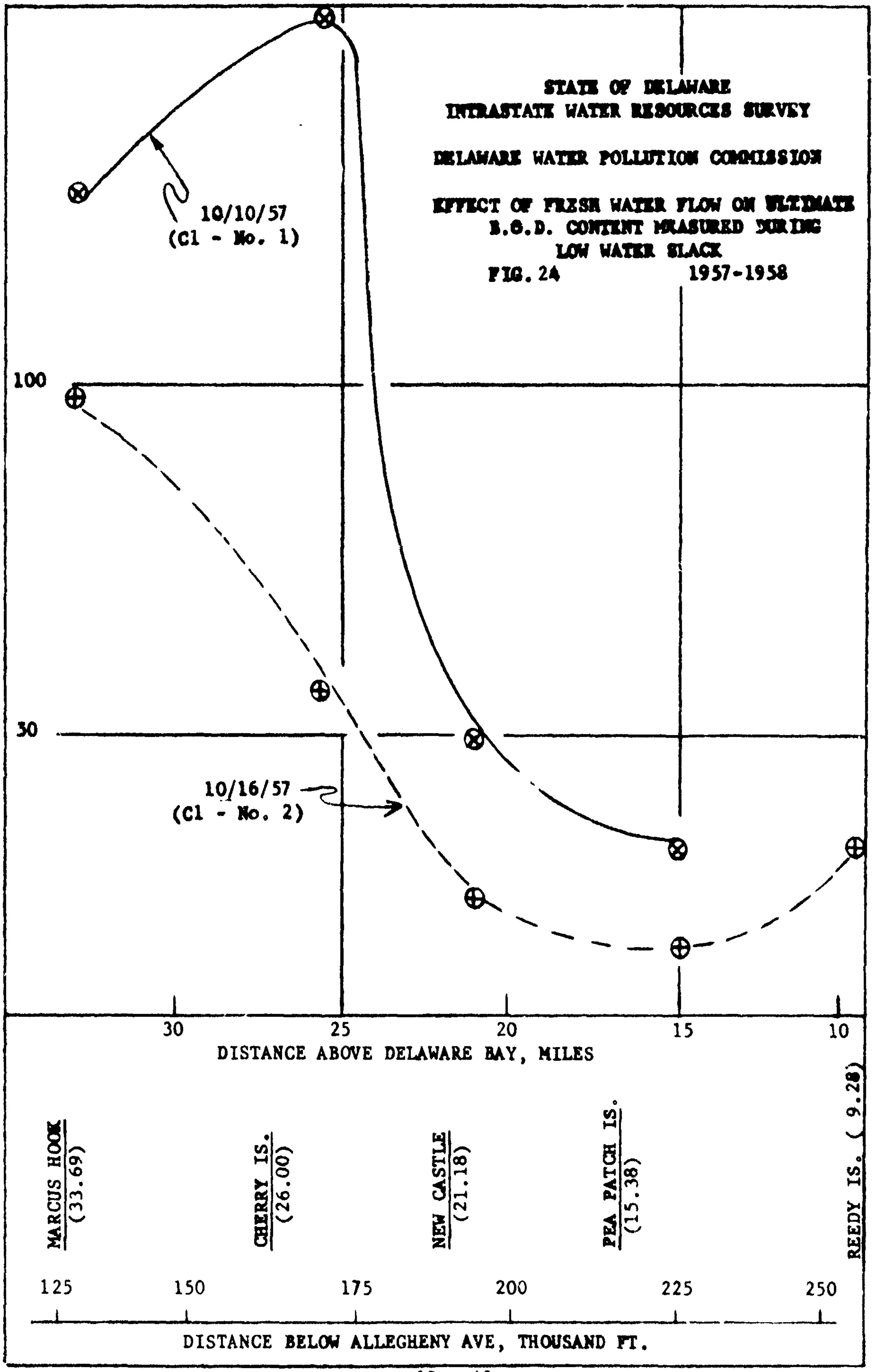


STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON DISSOLVED
OXYGEN CONTENT MEASURED DURING LOW WATER SLACK
FIG. 21 1957-1958
DISSOLVED OXYGEN IN EFFECTIVE VOL., LBS.
50
25
7/8/58
(Cl - No. 3)
8/5/58
(Cl-No. 2)
7/15/58
(Cl - No. 1)
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON DISSOLVED
OXYGEN CONTENT MEASURED DURING LOW WATER SLACK
FIG. 22
1957-1958
D.O. IN EFFECTIVE VOL., LBS.
50
25
9/15/58
(Cl-No.1)
6/19/58
(Cl - No. 4)
6/24/58
(Cl - No. 3)
6/4/57
(Cl - No. 2)
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
(33.69)
CHERRY IS.
(26.00)
NEW CASTLE
(21.18)
PEA PATCH IS.
(15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.


STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON ULTIMATE
B.O.D. CONTENT MEASURED DURING LOW WATER SLACK
FIG. 23 1957-1958
ULTIMATE BOD IN EFFECTIVE VOLUME, LBS.
200
100
7/1/58
(Cl - No. 3)
9/3/58
(Cl - No. 2)
8/29/57
(Cl - No. 1)
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.

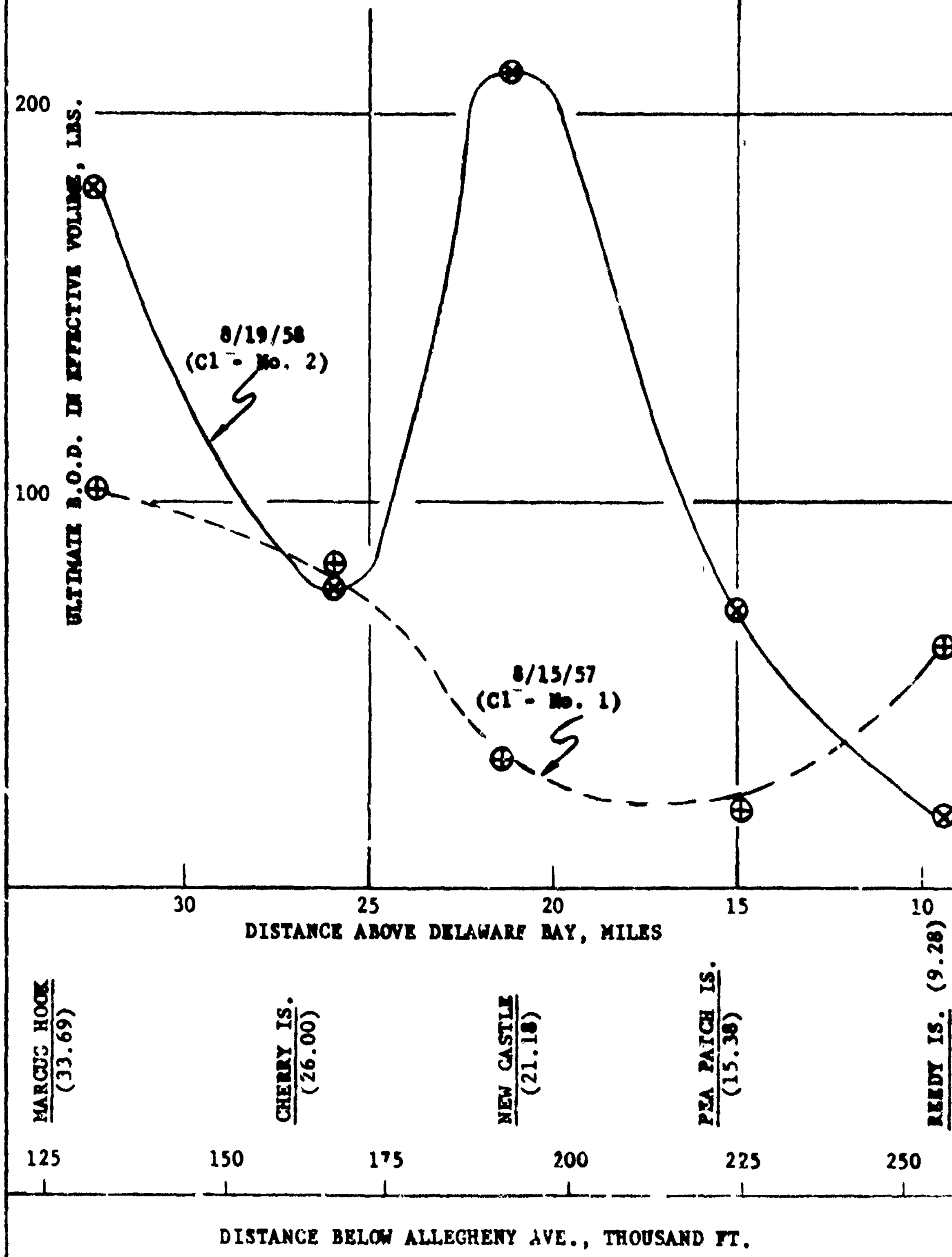

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON ULTIMATE
B.O.D. CONTENT MEASURED DURING
LOW WATER SLACK
FIG. 24 1957-1958
10/10/57
(Cl - No. 1)
10/16/57
(Cl - No. 2)
100
50
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE, THOUSAND FT.

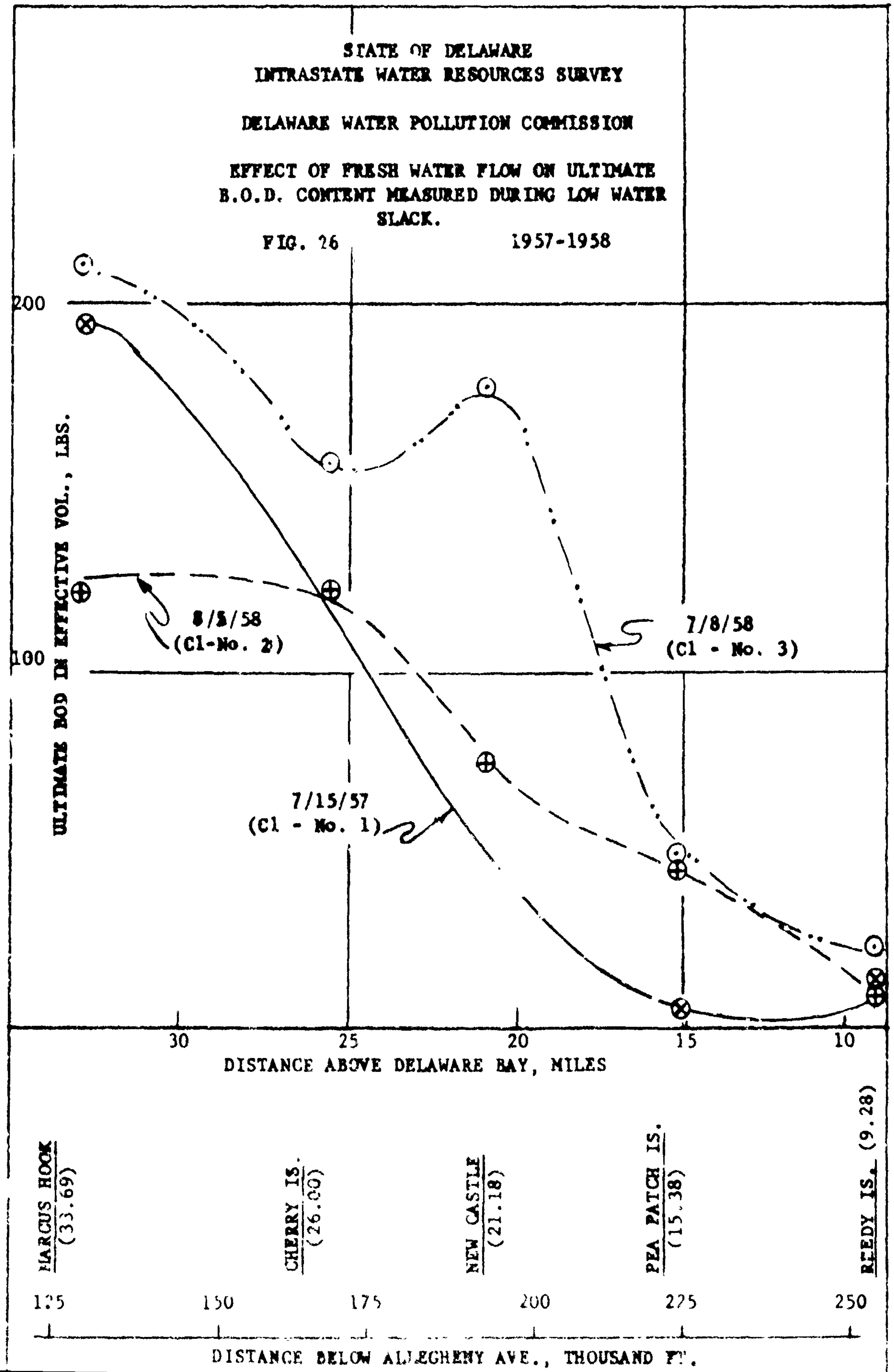
STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

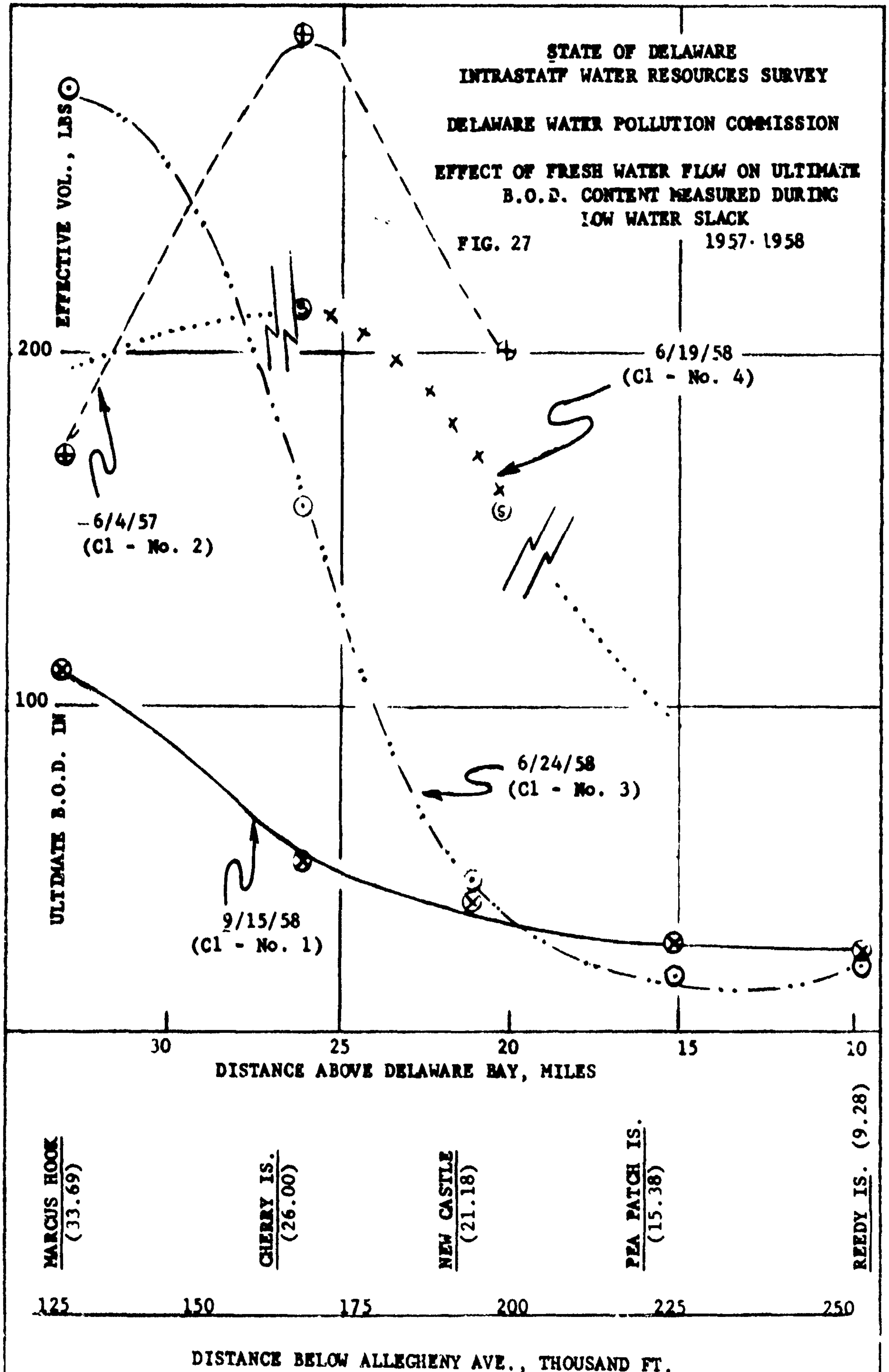
DELAWARE WATER POLLUTION COMMISSION

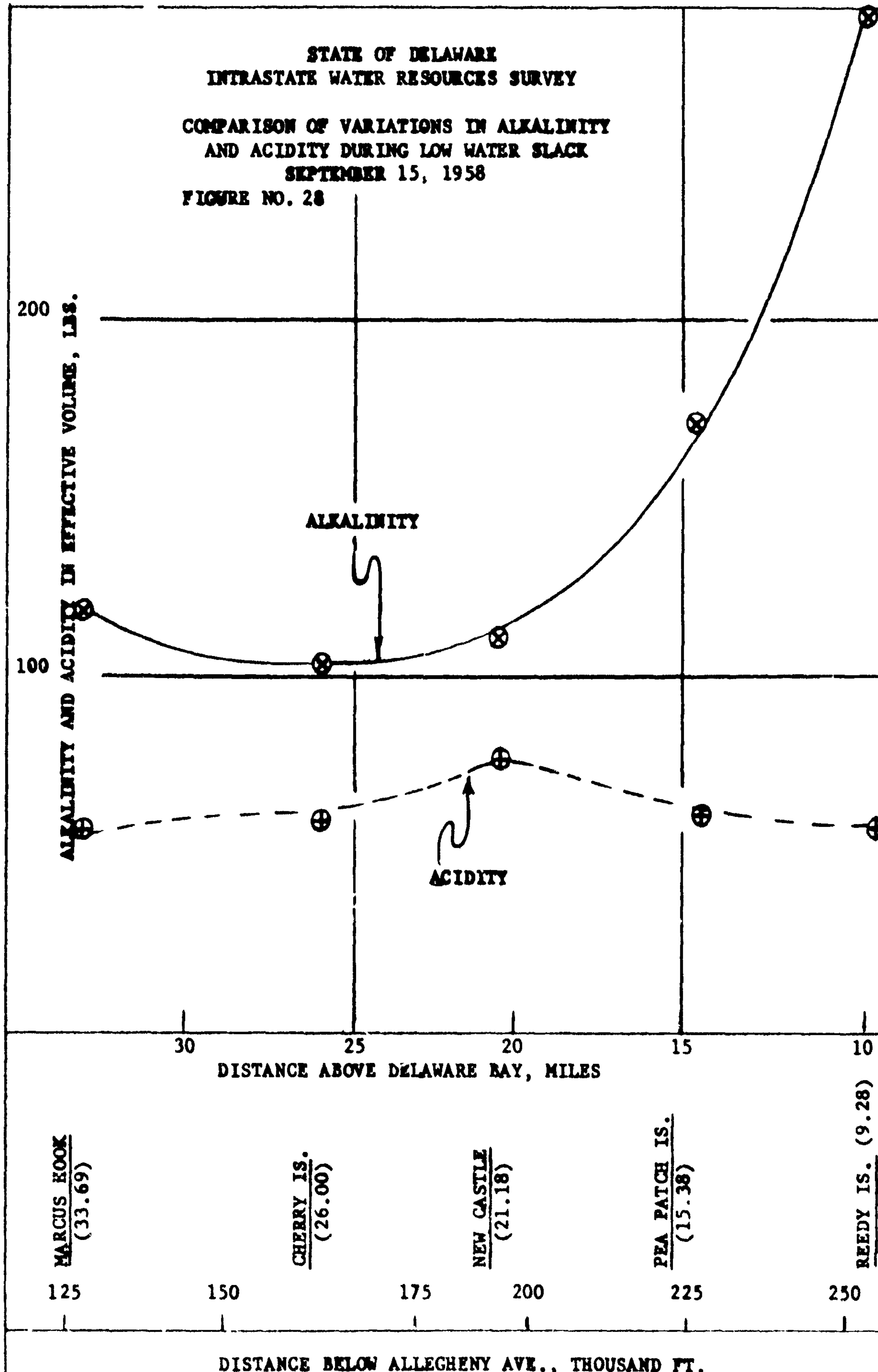
EFFECT OF FRESH WATER FLOW ON ULTIMATE BOD CONTENT MEASURED DURING LOW WATER SLACK

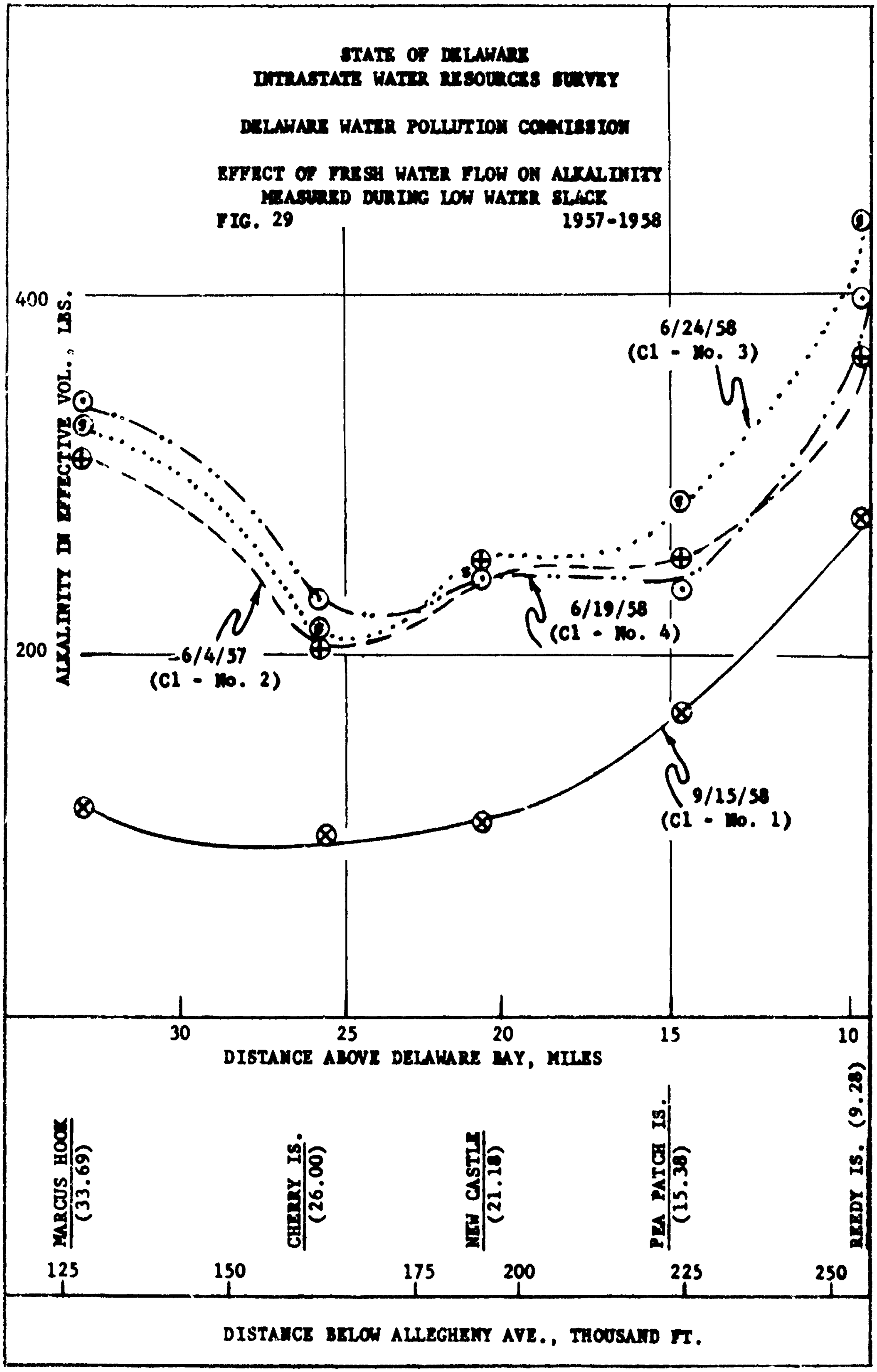
FIG. 25 1957-1958

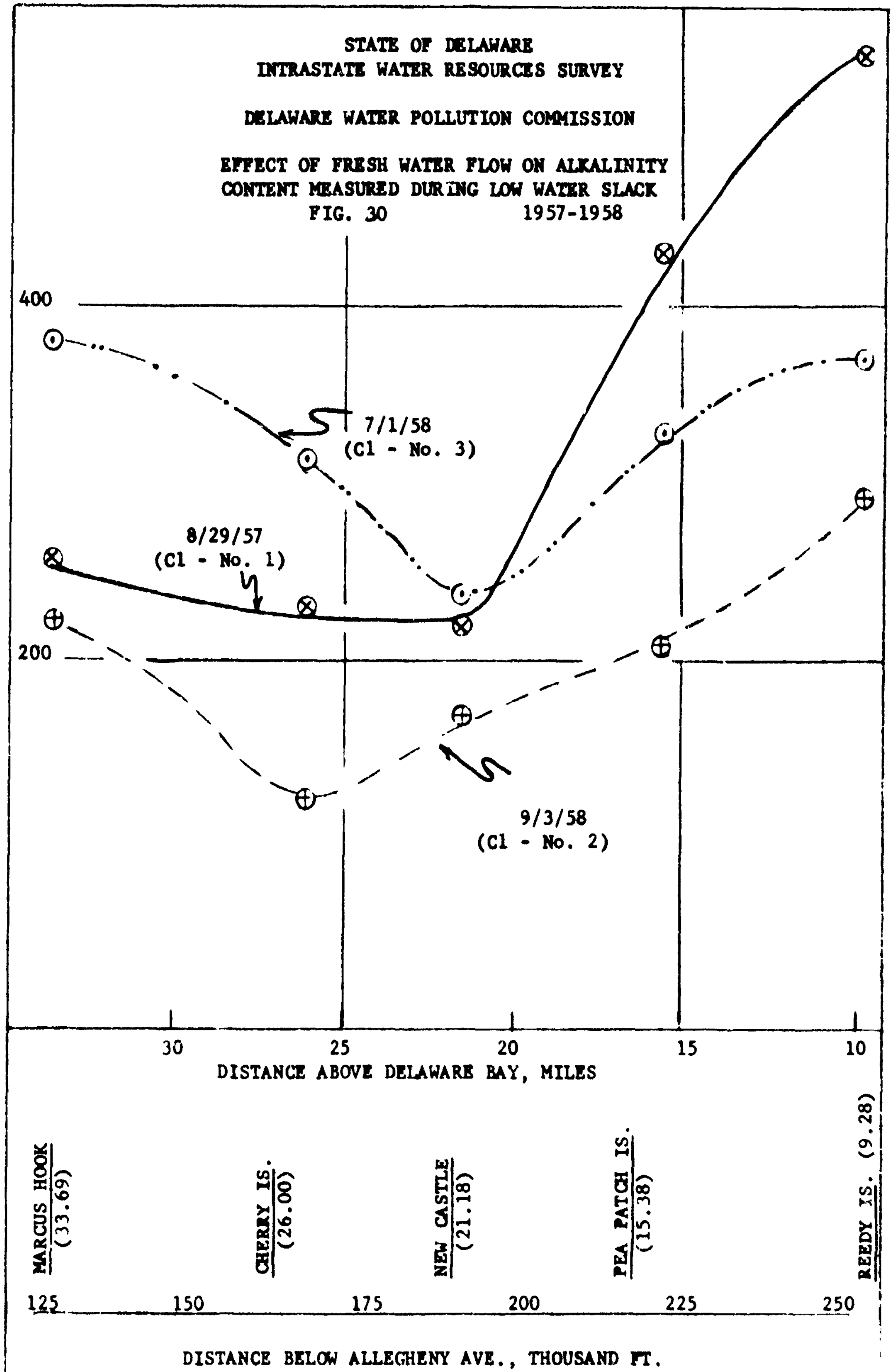


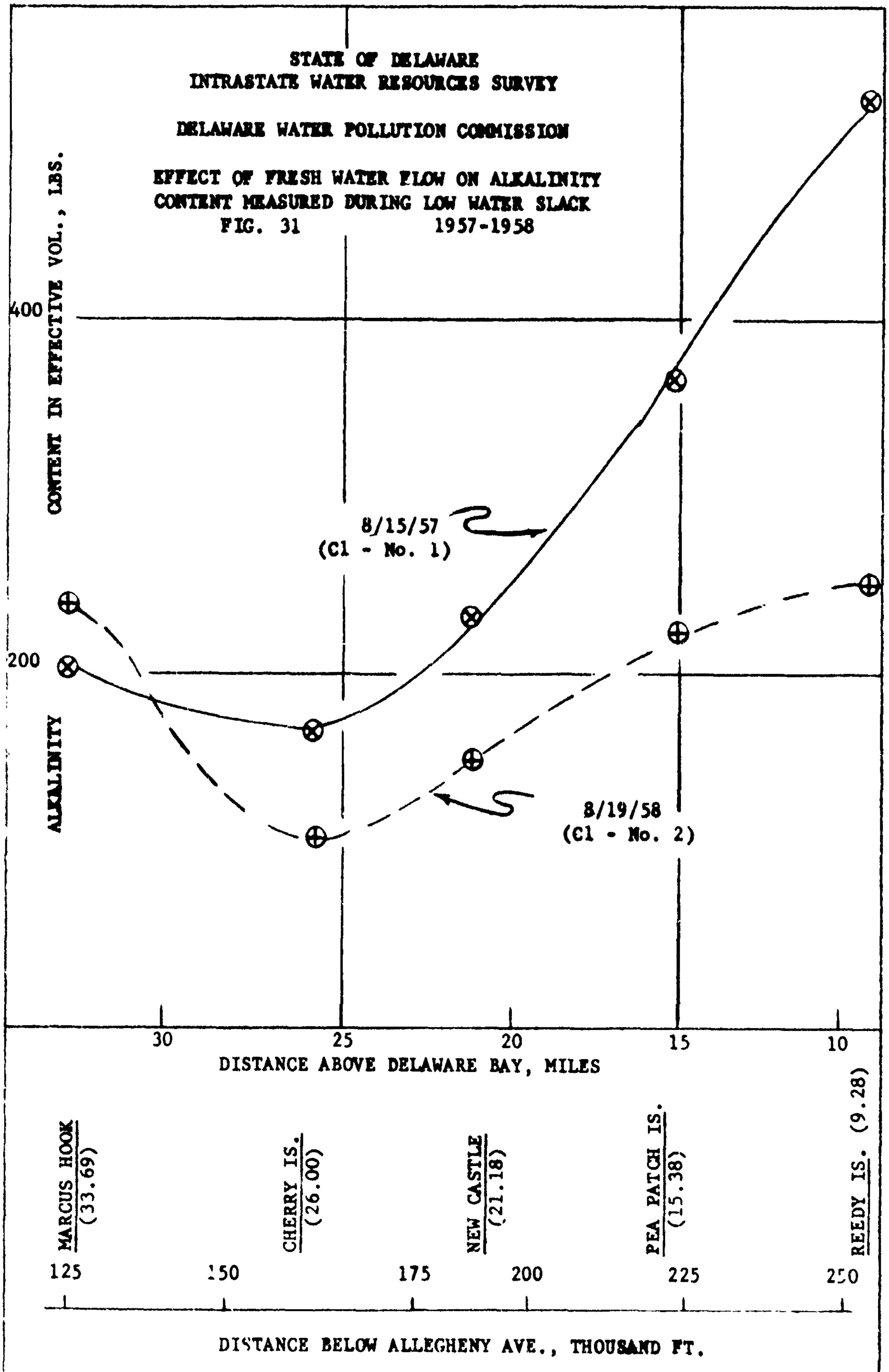

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON ULTIMATE B.O.D. CONTENT MEASURED DURING LOW WATER SLACK.
FIG. 26
1957-1958
ULTIMATE BOD IN EFFECTIVE VOL., LBS.
200
100
8/5/58 (Cl-No. 2)
7/8/58 (Cl - No. 3)
7/15/57 (Cl - No. 1)
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.

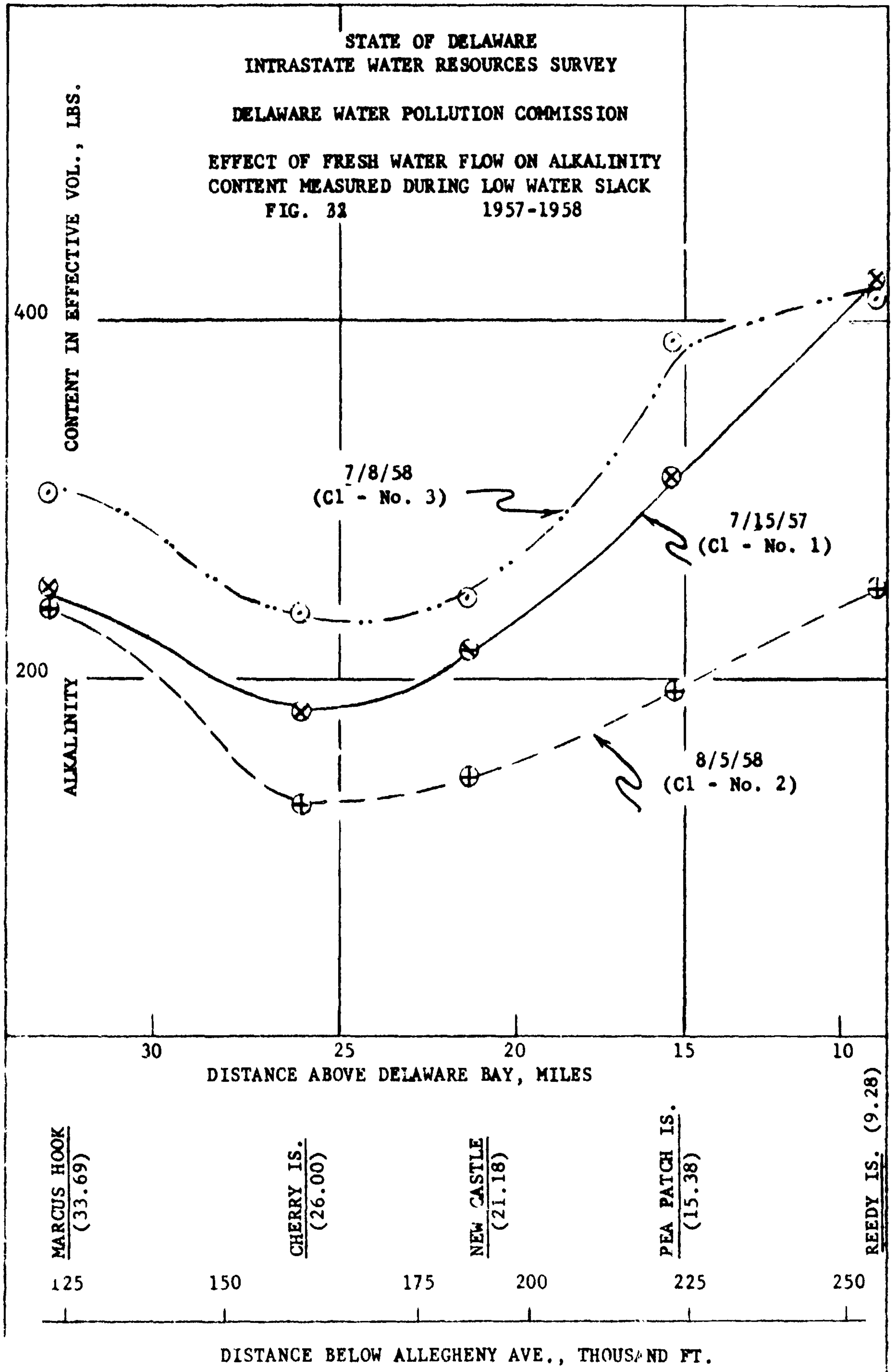

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON ULTIMATE B.O.D. CONTENT MEASURED DURING LOW WATER SLACK
FIG. 27
1957-1958
ULTIMATE B.O.D. IN EFFECTIVE VOL., LBS
200
100
6/19/58 (Cl - No. 4)
6/4/57 (Cl - No. 2)
6/24/58 (Cl - No. 3)
9/15/58 (Cl - No. 1)
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.

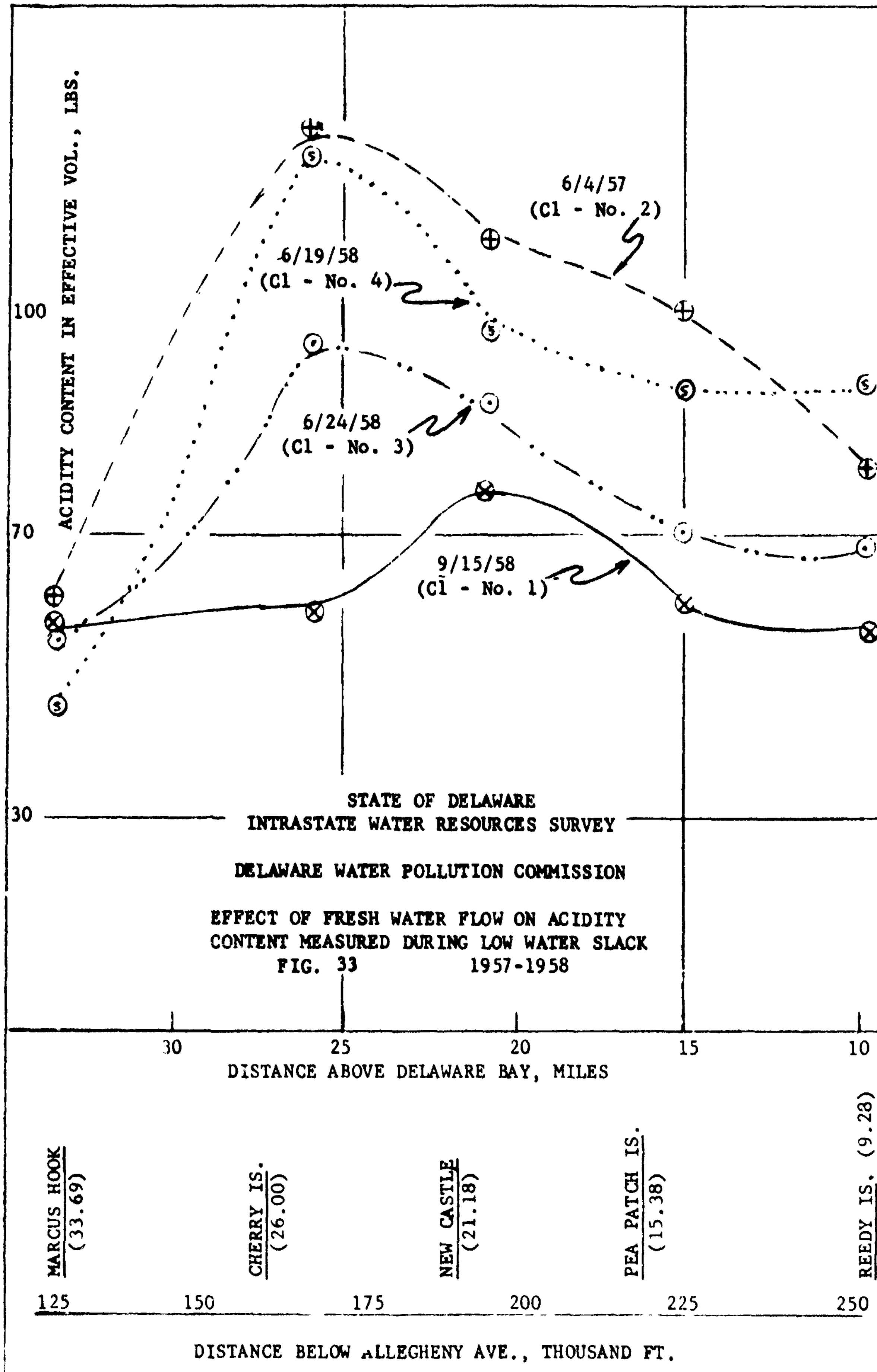

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
COMPARISON OF VARIATIONS IN ALKALINITY
AND ACIDITY DURING LOW WATER SLACK
SEPTEMBER 15, 1958
FIGURE NO. 28
ALKALINITY AND ACIDITY IN EFFECTIVE VOLUME, LBS.
200
100
ALKALINITY
ACIDITY
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.


STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON ALKALINITY
MEASURED DURING LOW WATER SLACK
FIG. 29
1957-1958
ALKALINITY IN EFFECTIVE VOL., LBS.
400
200
6/24/58
(Cl - No. 3)
6/19/58
(Cl - No. 4)
6/4/57
(Cl - No. 2)
9/15/58
(Cl - No. 1)
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.


STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON ALKALINITY
CONTENT MEASURED DURING LOW WATER SLACK
FIG. 30 1957-1958
400
200
7/1/58
(Cl - No. 3)
8/29/57
(Cl - No. 1)
9/3/58
(Cl - No. 2)
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.


STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON ALKALINITY
CONTENT MEASURED DURING LOW WATER SLACK
FIG. 31 1957-1958
ALKALINITY CONTENT IN EFFECTIVE VOL., LBS.
400
200
8/15/57
(Cl - No. 1)
8/19/58
(Cl - No. 2)
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.


STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON ALKALINITY
CONTENT MEASURED DURING LOW WATER SLACK
FIG. 32 1957-1958
ALKALINITY CONTENT IN EFFECTIVE VOL., LBS.
400
200
7/8/58
(Cl - No. 3)
7/15/57
(Cl - No. 1)
8/5/58
(Cl - No. 2)
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

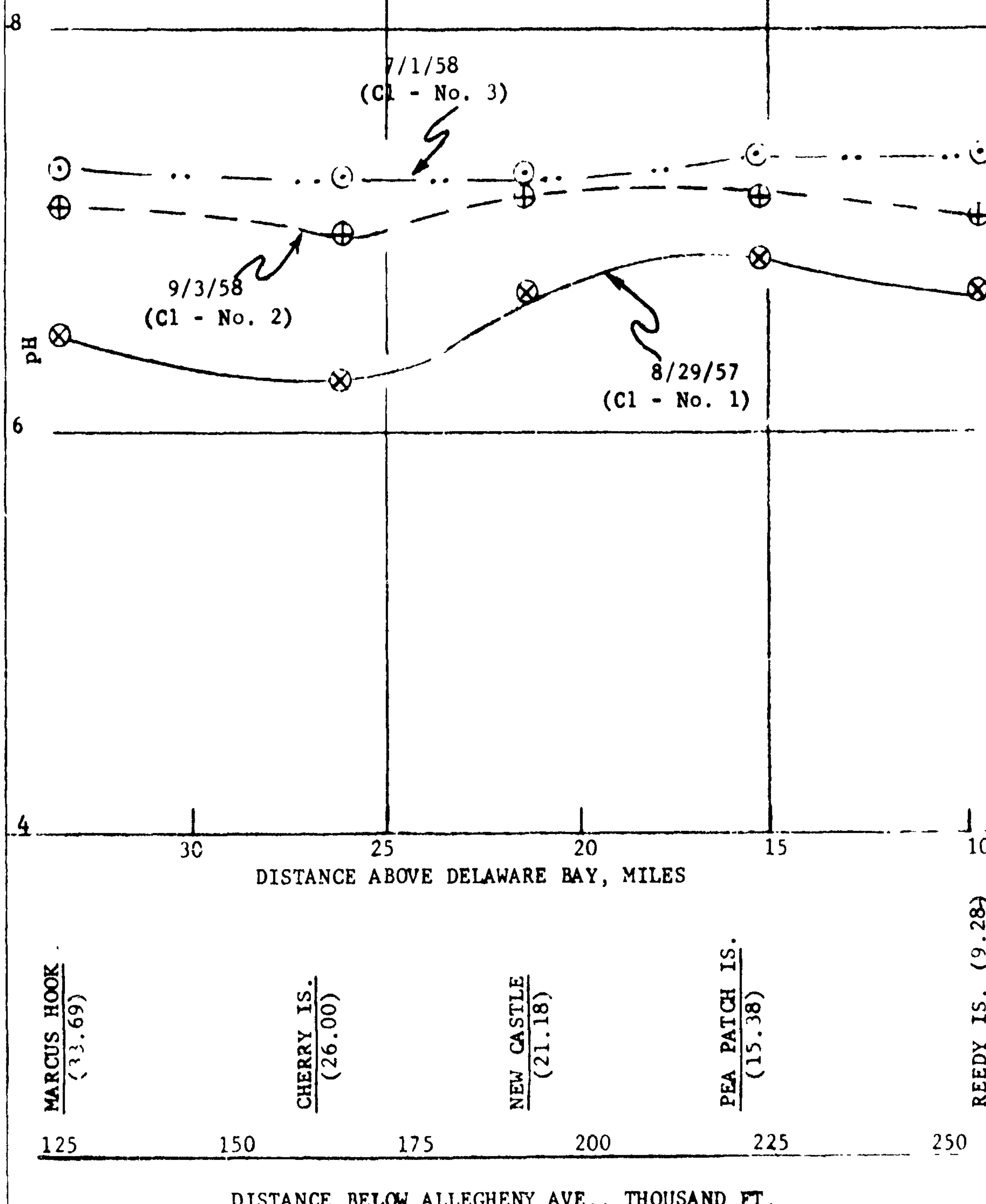
EFFECT OF FRESH WATER FLOW ON ACIDITY
CONTENT MEASURED DURING LOW WATER SLACK
FIG. 33 1957-1958

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

VARIATIONS IN pH WITH FRESH WATER FLOW
DURING LOW WATER SLACK

FIG. 34 1957-1958

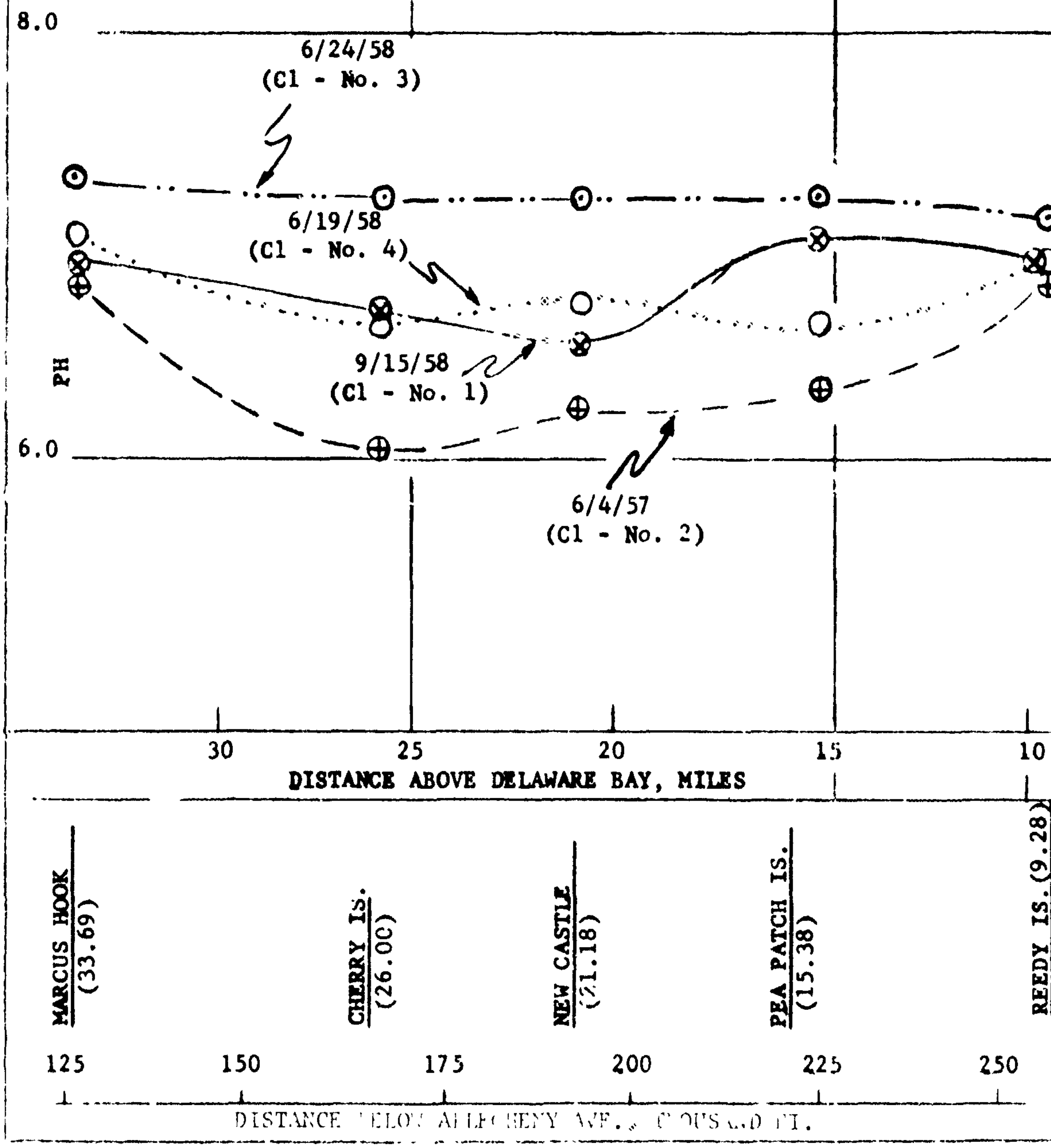


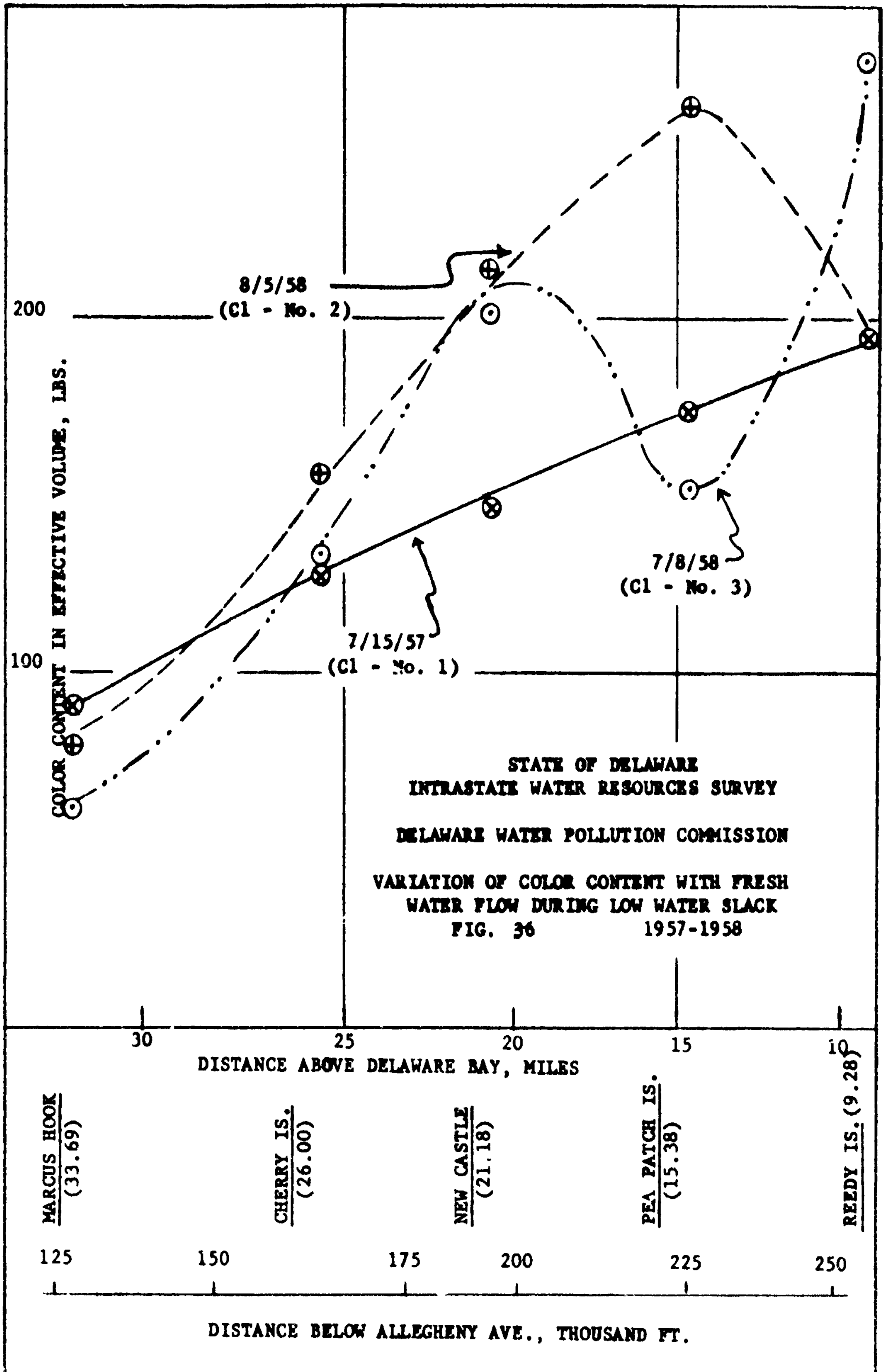
STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

VARIATIONS OF pH WITH FRESH WATER FLOW
DURING LOW WATER SLACK

FIG. 35 1957-1958





STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

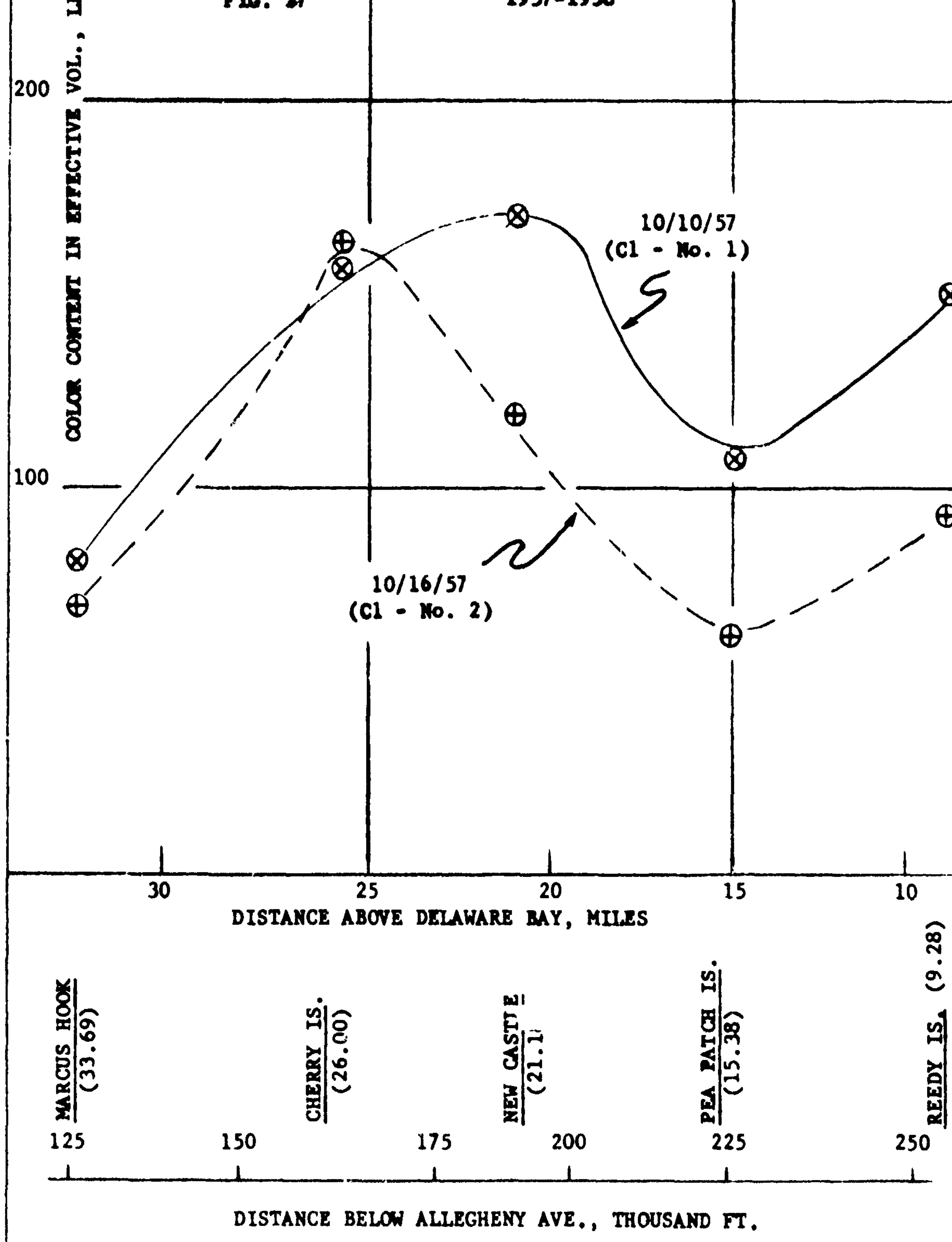
VARIATION OF COLOR CONTENT WITH FRESH WATER FLOW DURING LOW WATER SLACK
FIG. 36 1957-1958

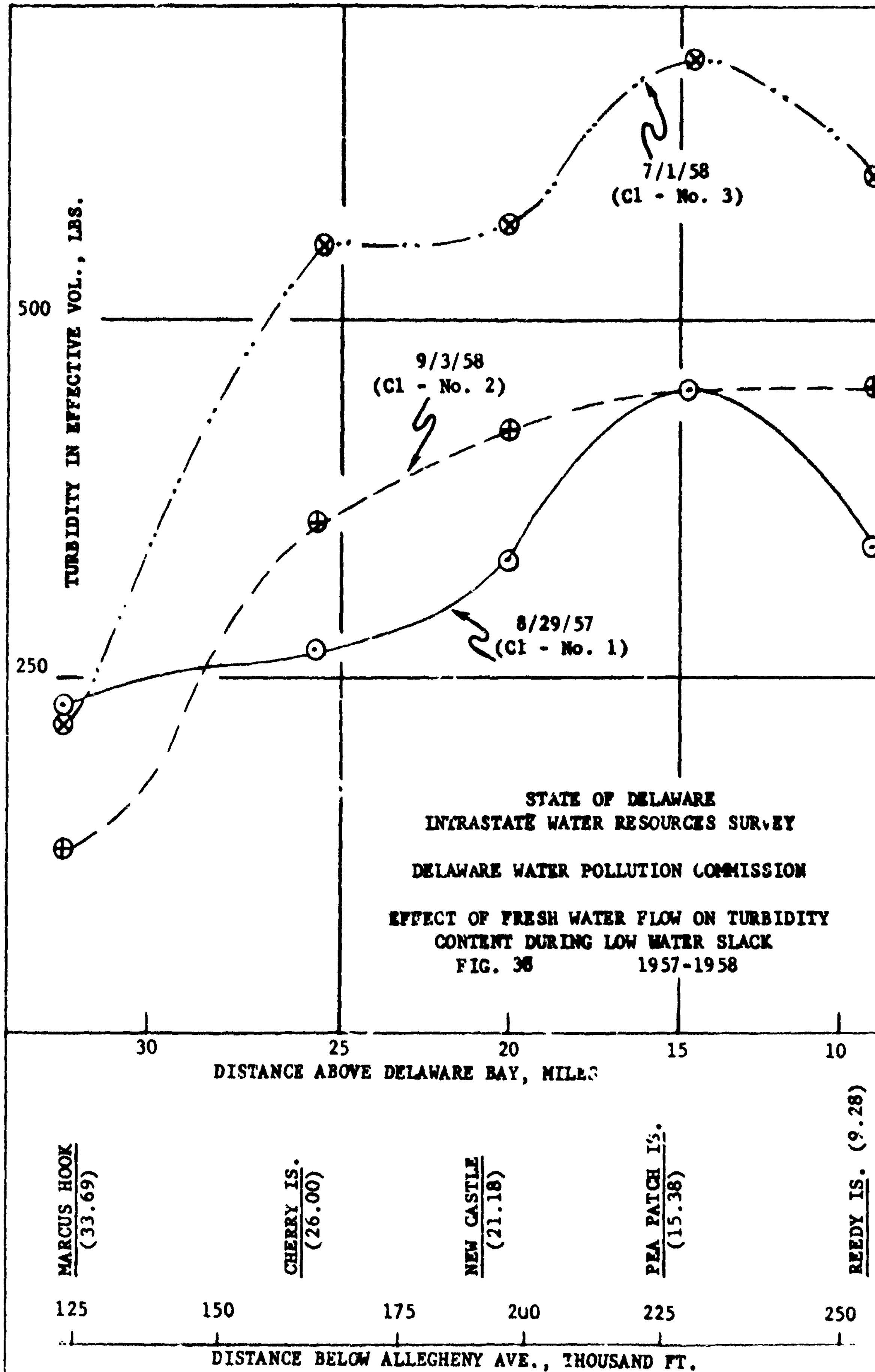
STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

VARIATIONS IN COLOR CONTENT WITH FRESH WATER FLOW DURING LOW WATER SLACK

FIG. 27 1957-1958

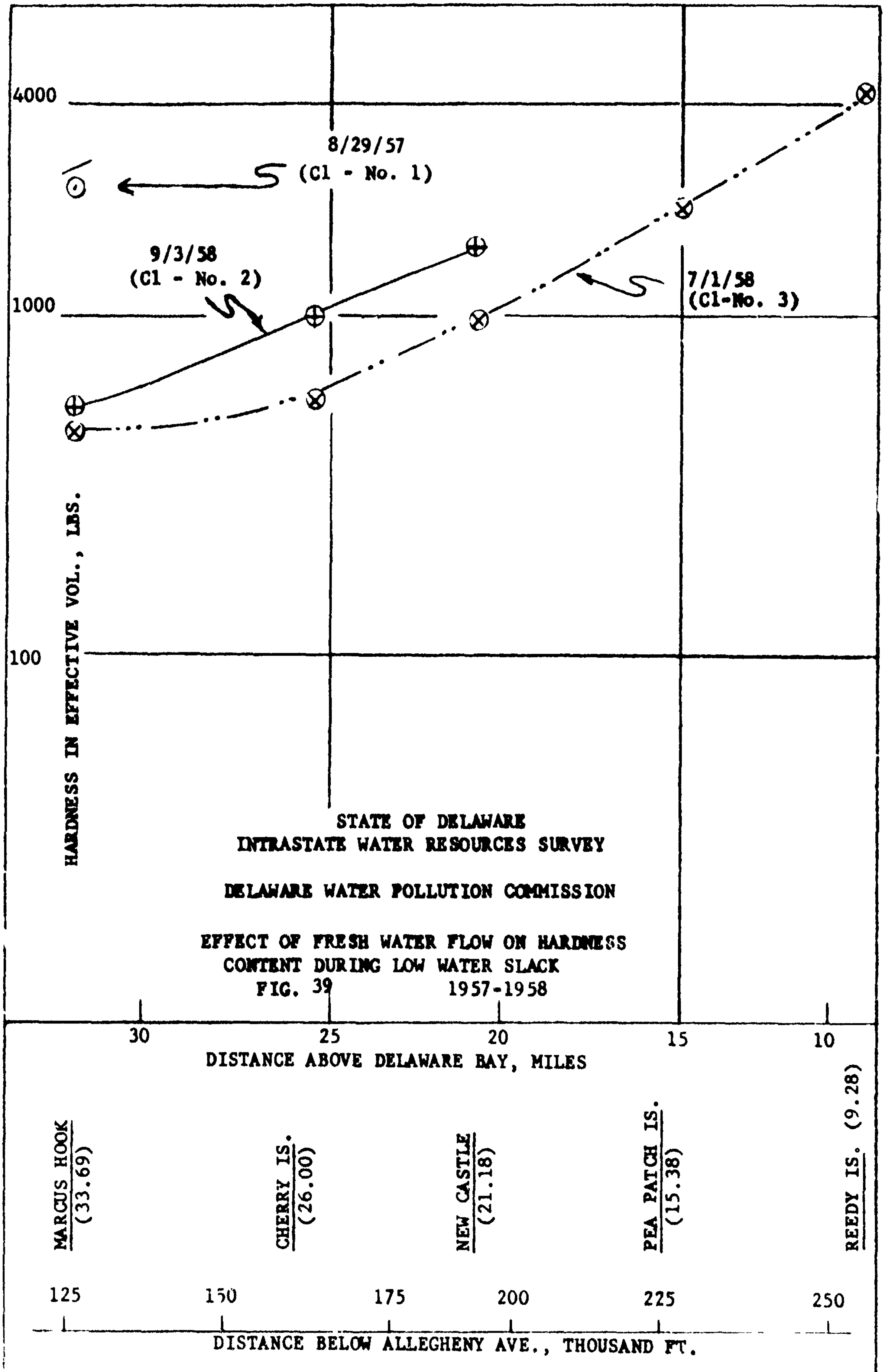




STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

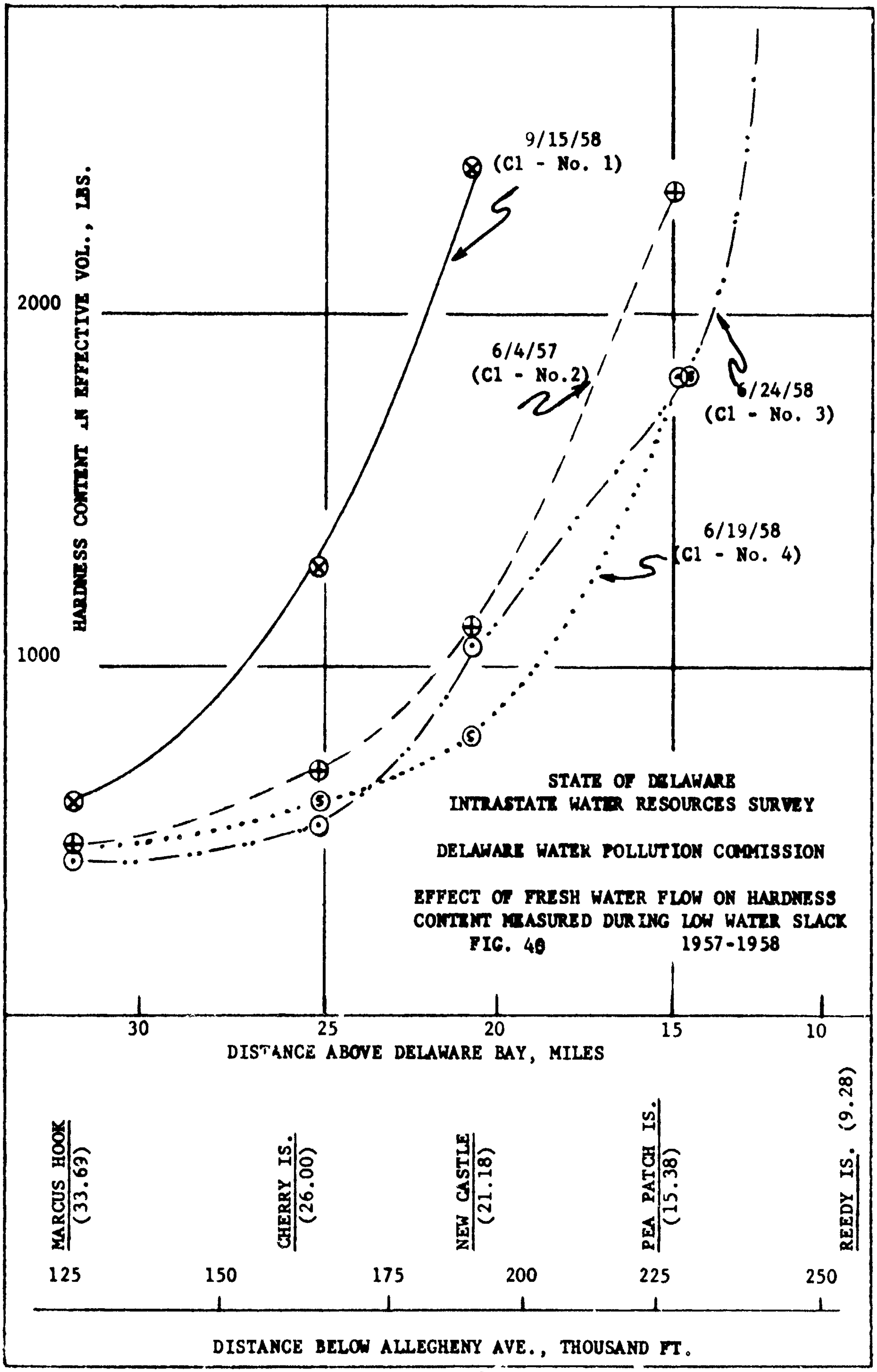
EFFECT OF FRESH WATER FLOW ON TURBIDITY CONTENT DURING LOW WATER SLACK
FIG. 36 1957-1958



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

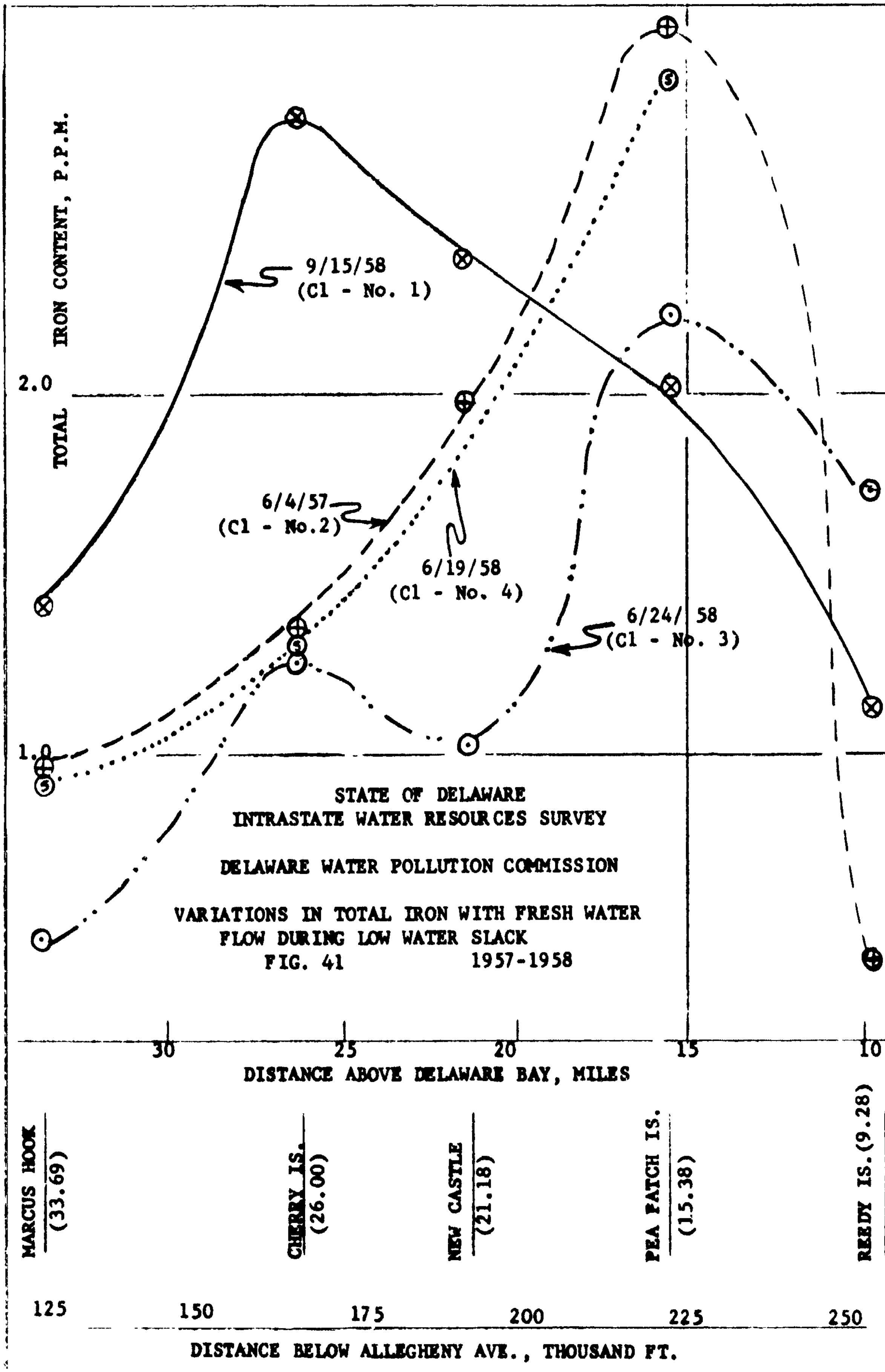
EFFECT OF FRESH WATER FLOW ON HARDNESS
CONTENT DURING LOW WATER SLACK
FIG. 39 1957-1958



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

EFFECT OF FRESH WATER FLOW ON HARDNESS CONTENT MEASURED DURING LOW WATER SLACK
FIG. 48 1957-1958



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

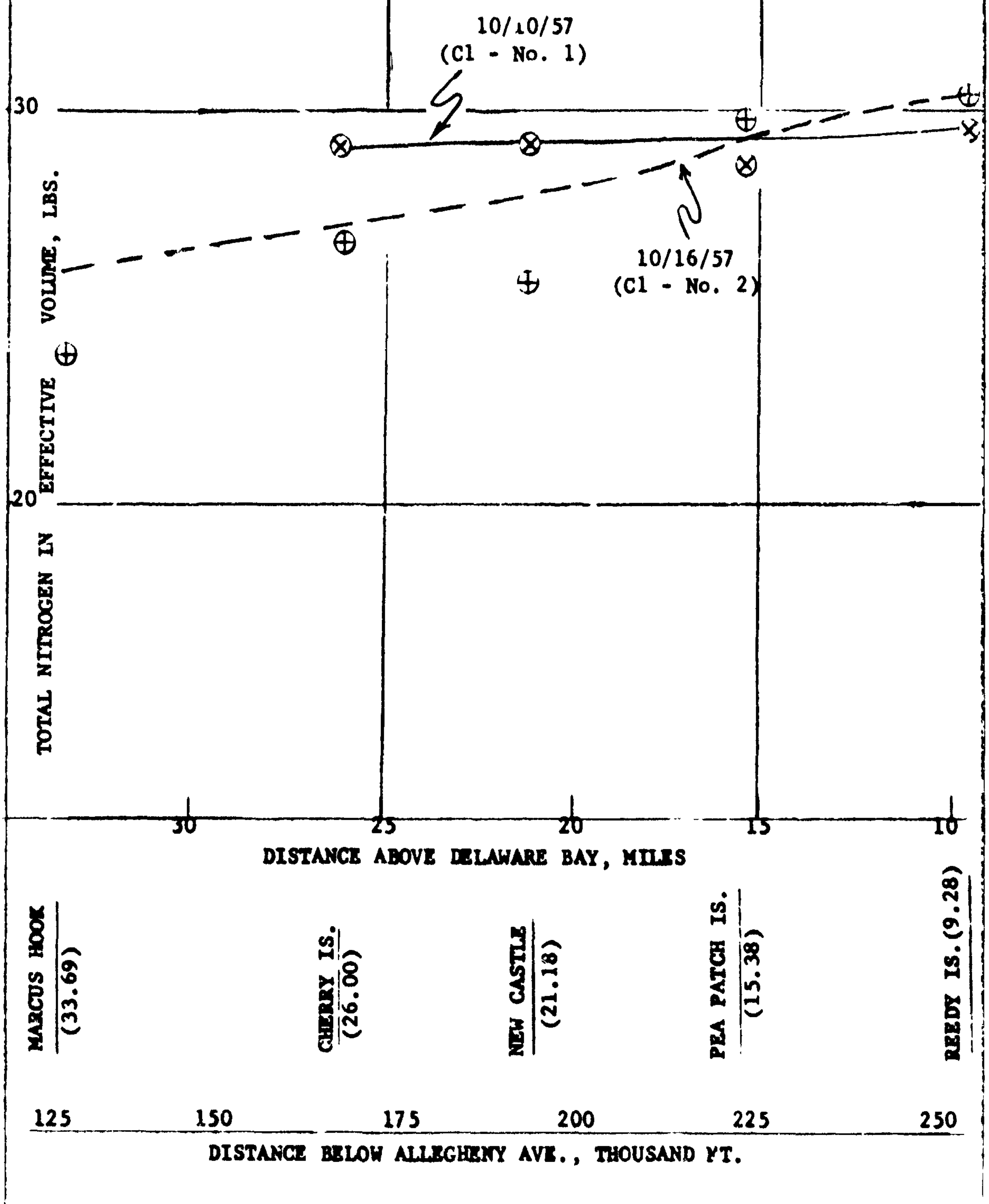
VARIATIONS IN TOTAL IRON WITH FRESH WATER FLOW DURING LOW WATER SLACK
FIG. 41 1957-1958

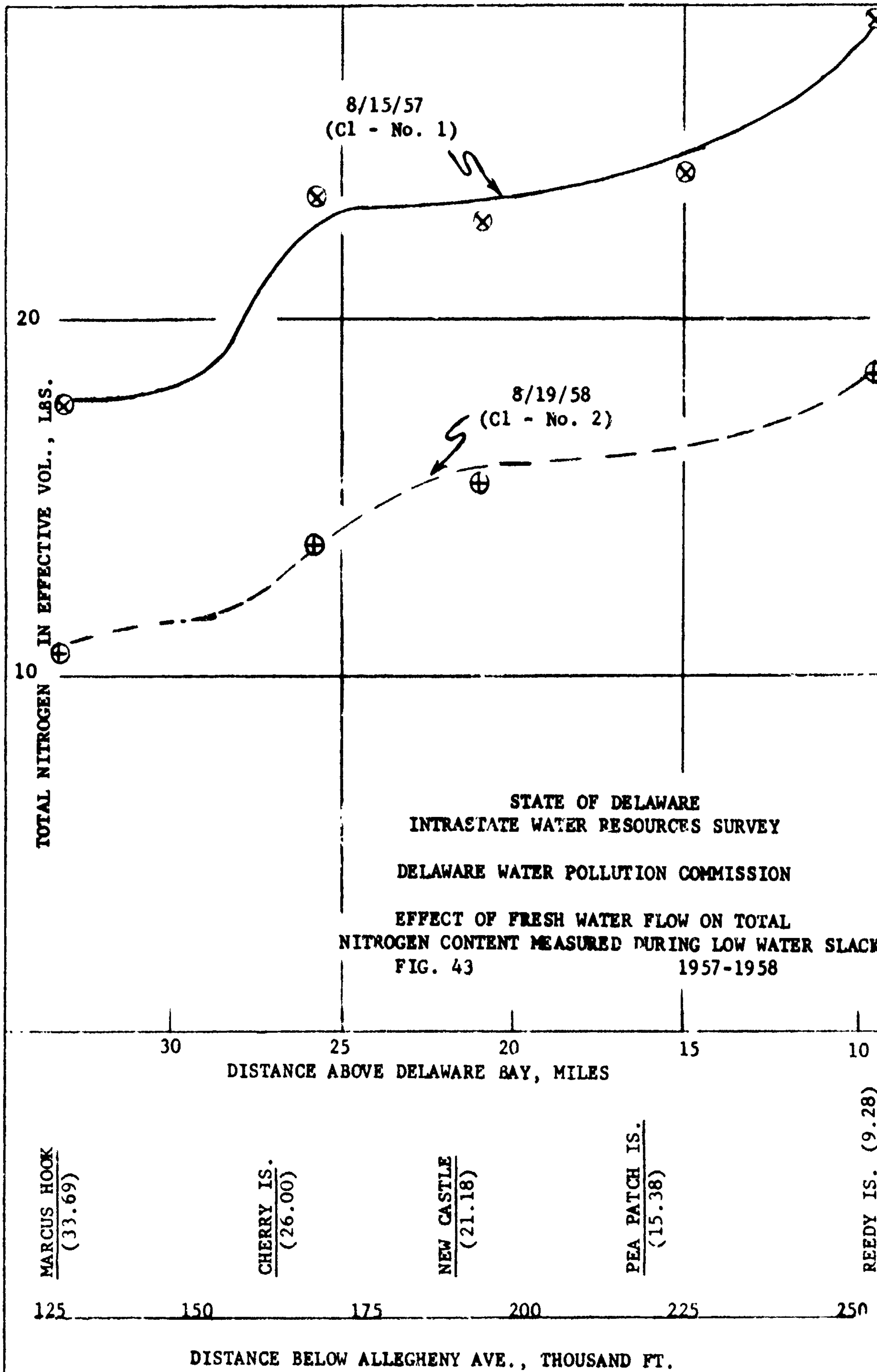
STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

EFFECT OF FRESH WATER FLOW ON TOTAL
NITROGEN CONTENT MEASURED DURING LOW WATER SLACK

FIG. 42 1957-1958



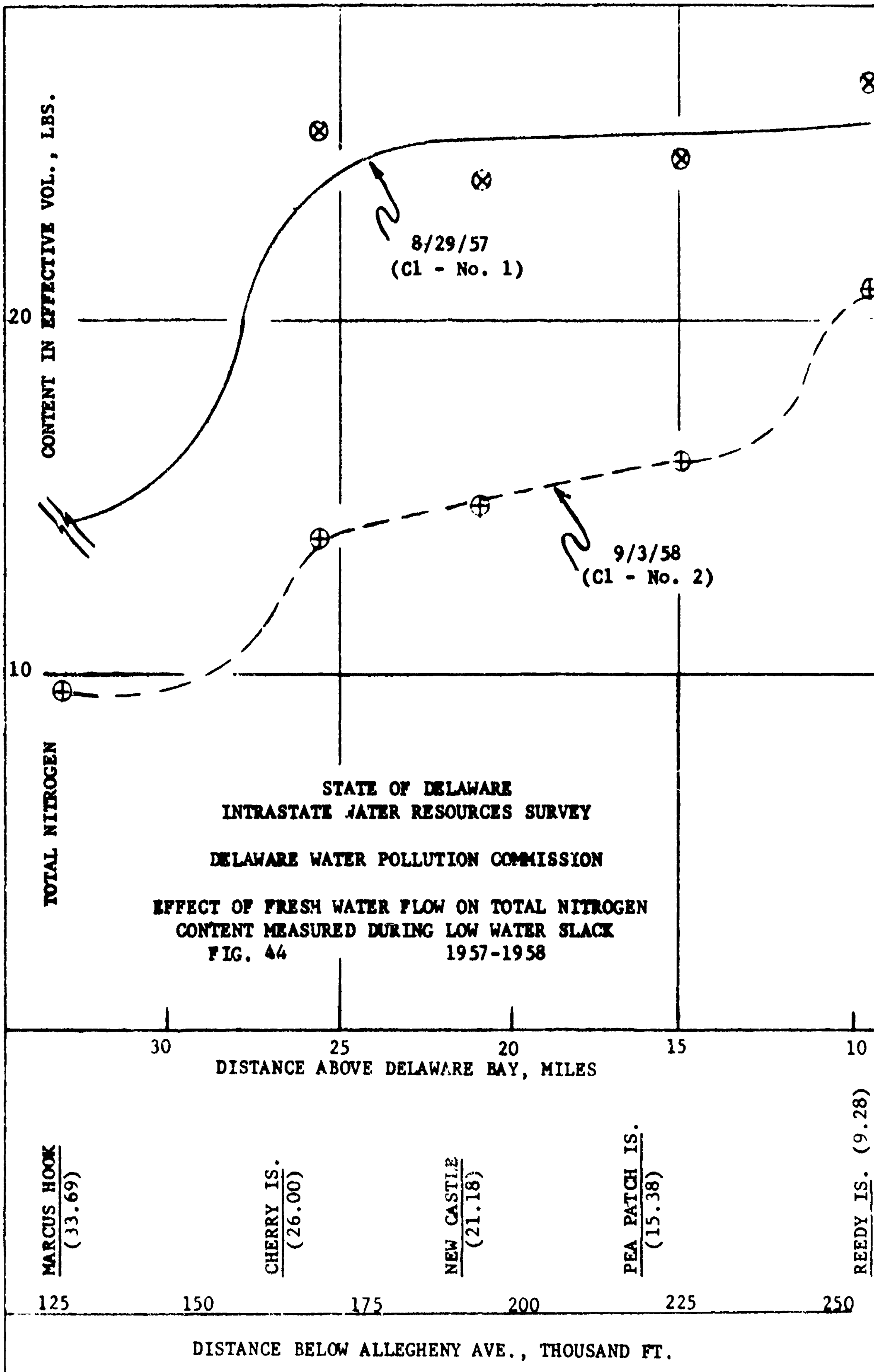


STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

EFFECT OF FRESH WATER FLOW ON TOTAL NITROGEN CONTENT MEASURED DURING LOW WATER SLACK

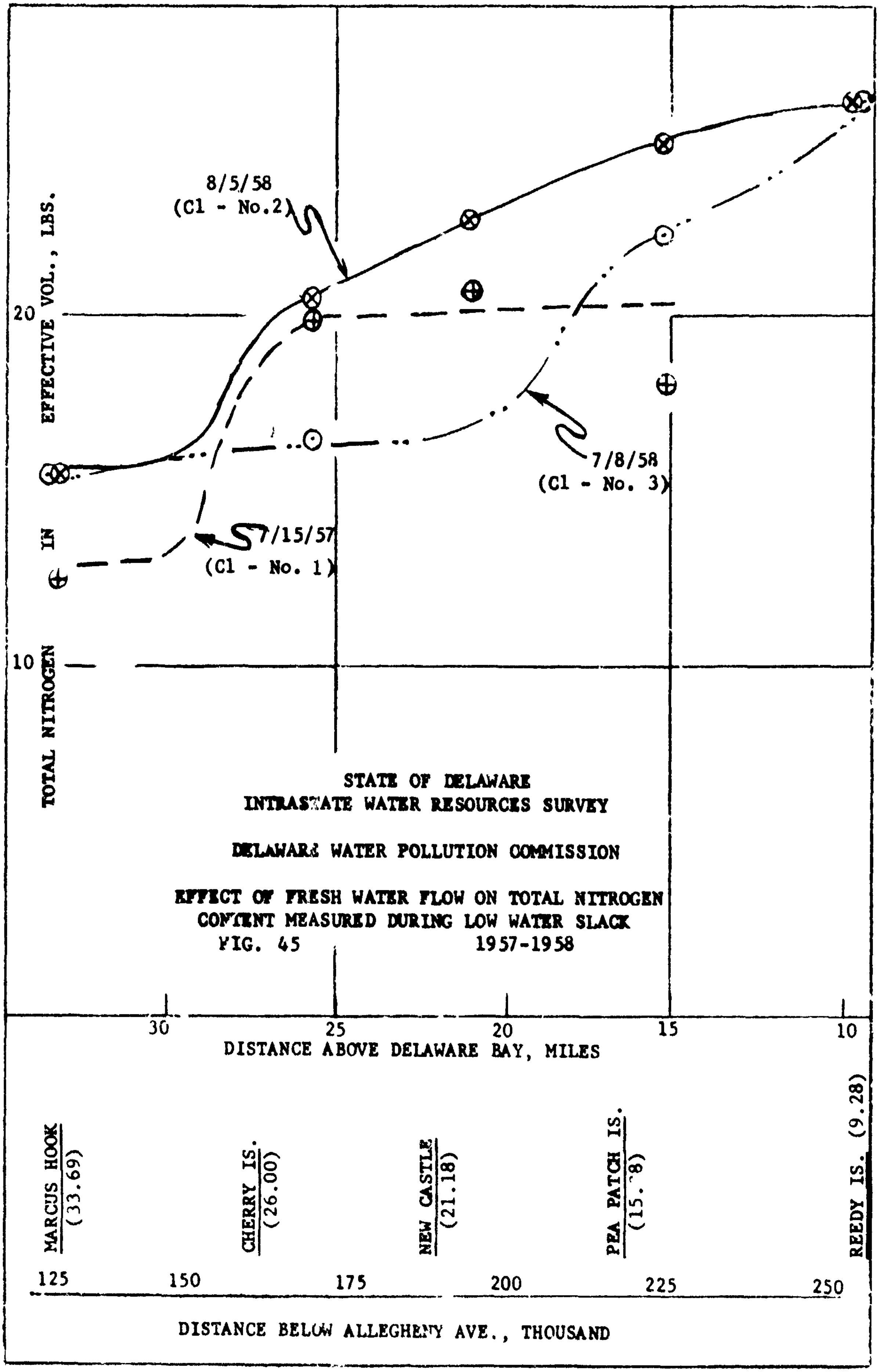
FIG. 43 1957-1958



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

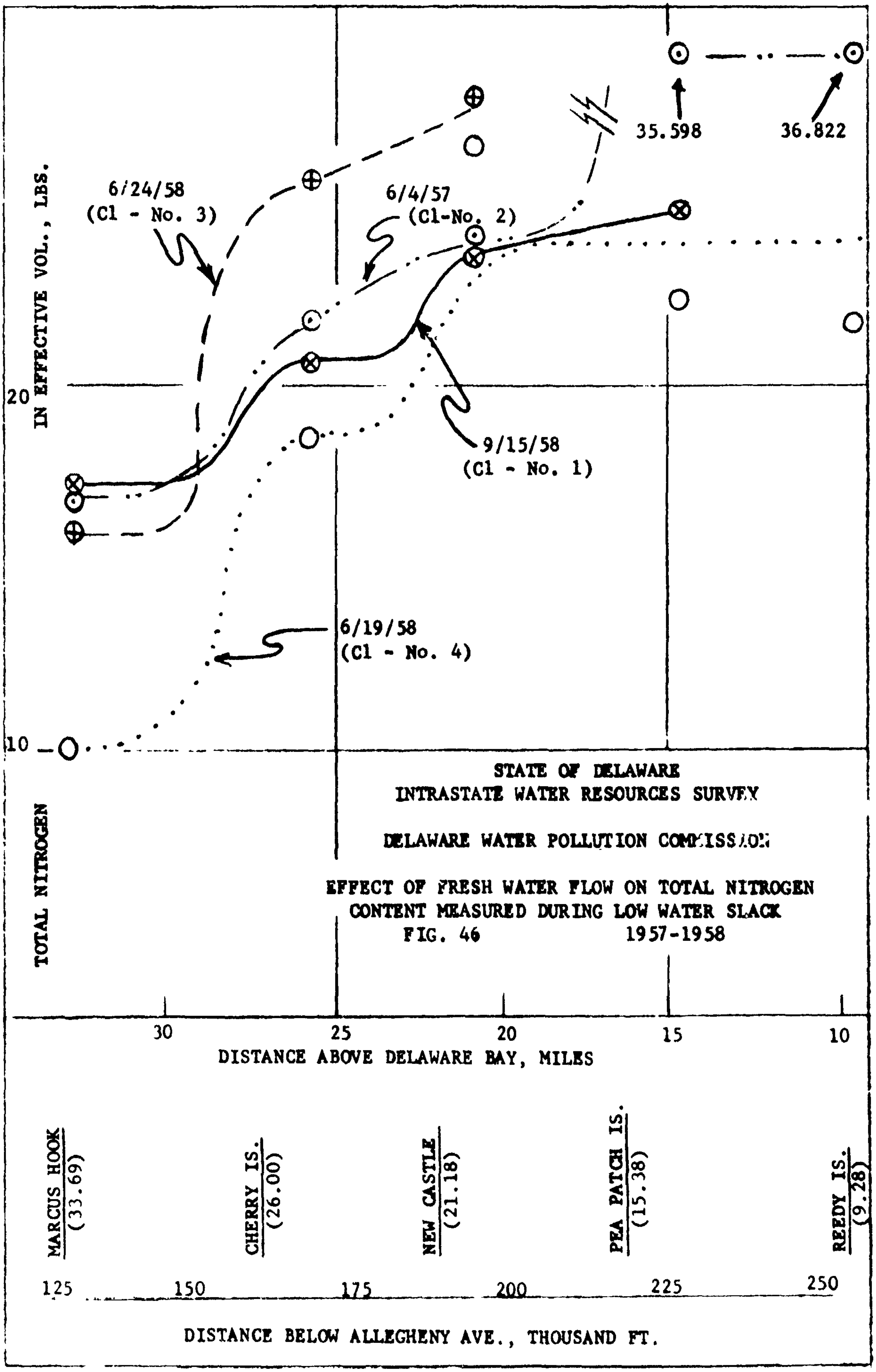
EFFECT OF FRESH WATER FLOW ON TOTAL NITROGEN
CONTENT MEASURED DURING LOW WATER SLACK
FIG. 44 1957-1958



STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

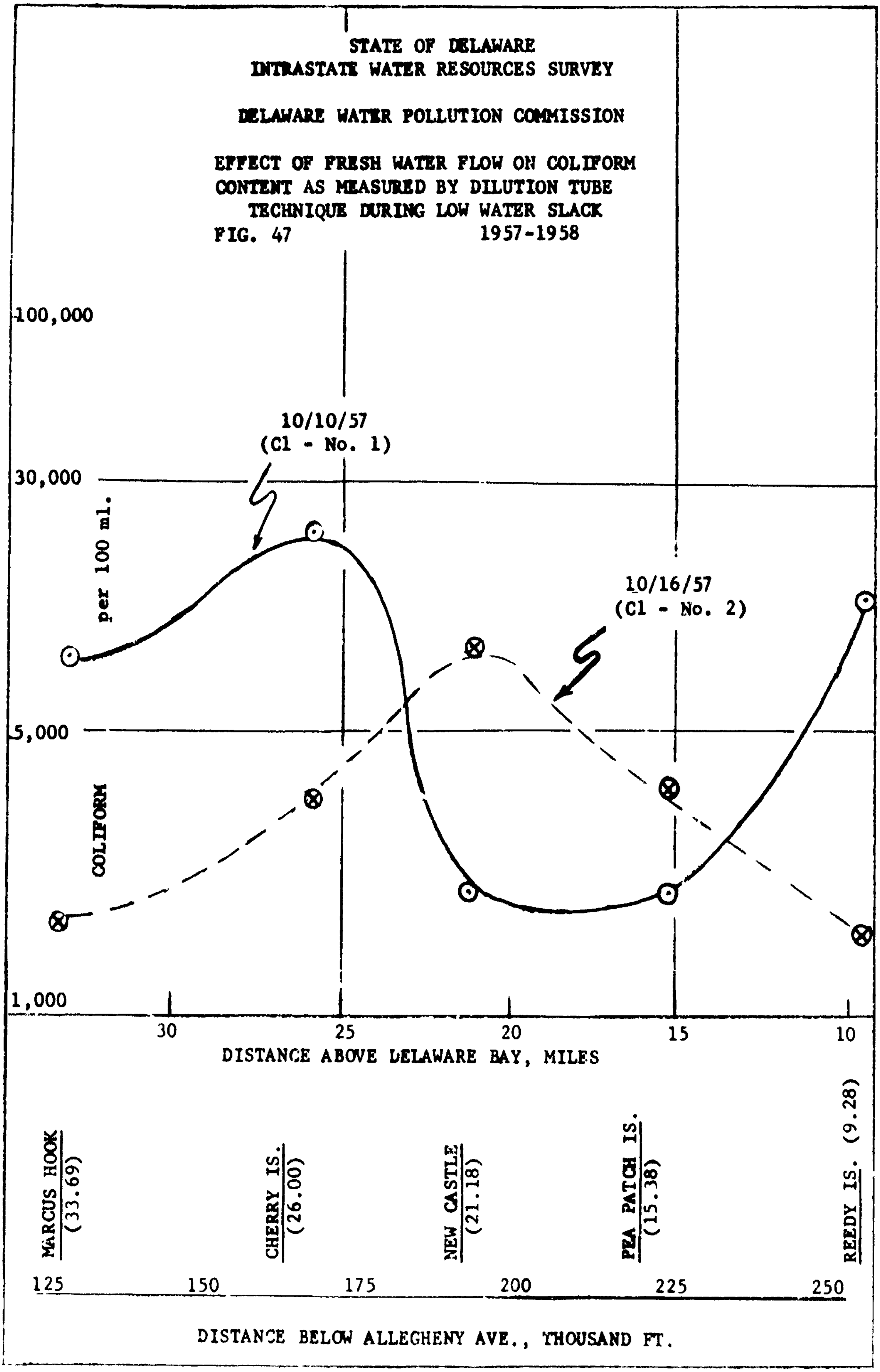
EFFECT OF FRESH WATER FLOW ON TOTAL NITROGEN
CONTENT MEASURED DURING LOW WATER SLACK
FIG. 45 1957-1958

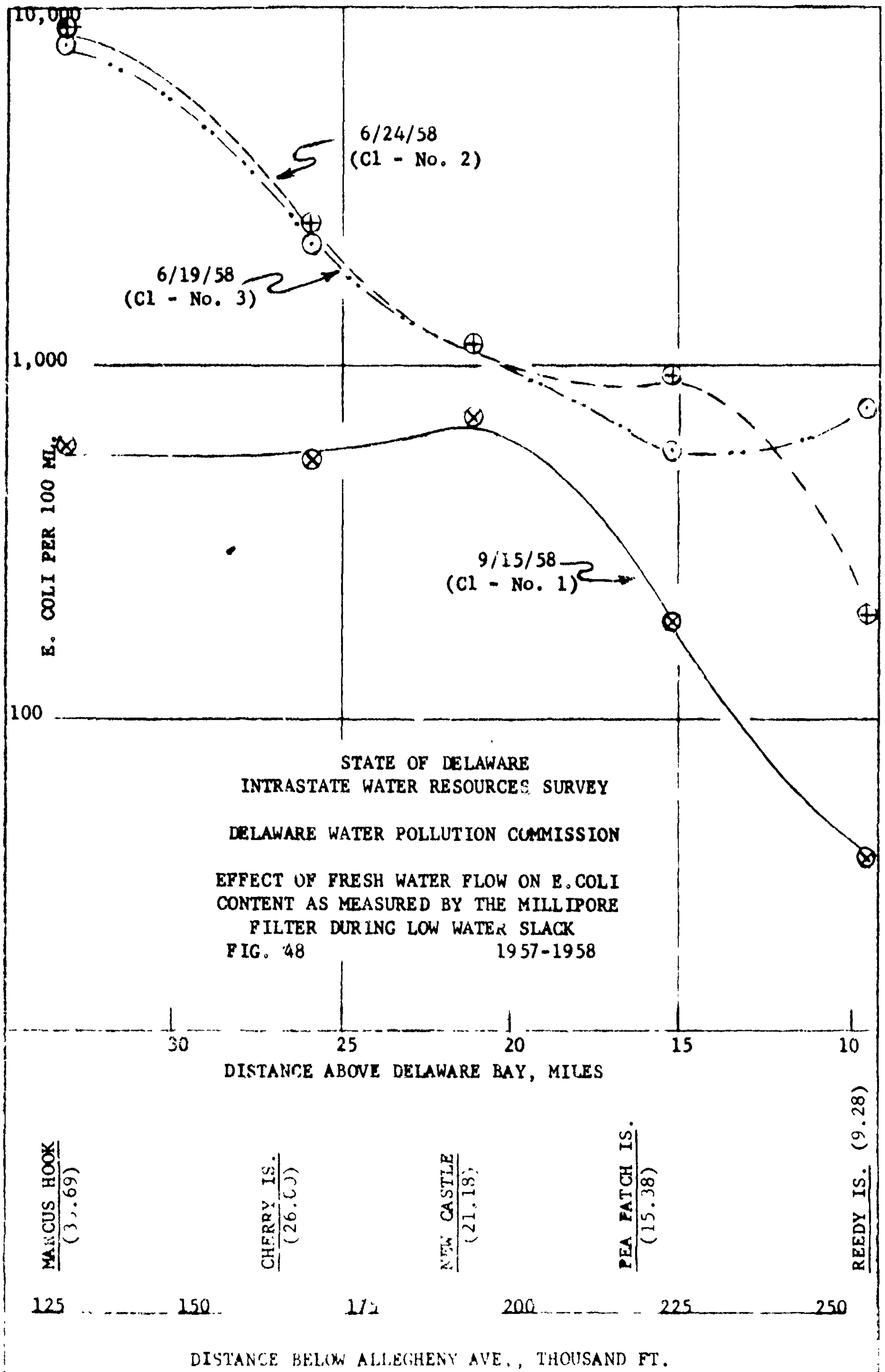


STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

EFFECT OF FRESH WATER FLOW ON TOTAL NITROGEN CONTENT MEASURED DURING LOW WATER SLACK
FIG. 46 1957-1958


STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON COLIFORM CONTENT AS MEASURED BY DILUTION TUBE TECHNIQUE DURING LOW WATER SLACK
FIG. 47
1957-1958
100,000
30,000
5,000
1,000
COLIFORM per 100 ml.
10/10/57
(Cl - No. 1)
10/16/57
(Cl - No. 2)
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.

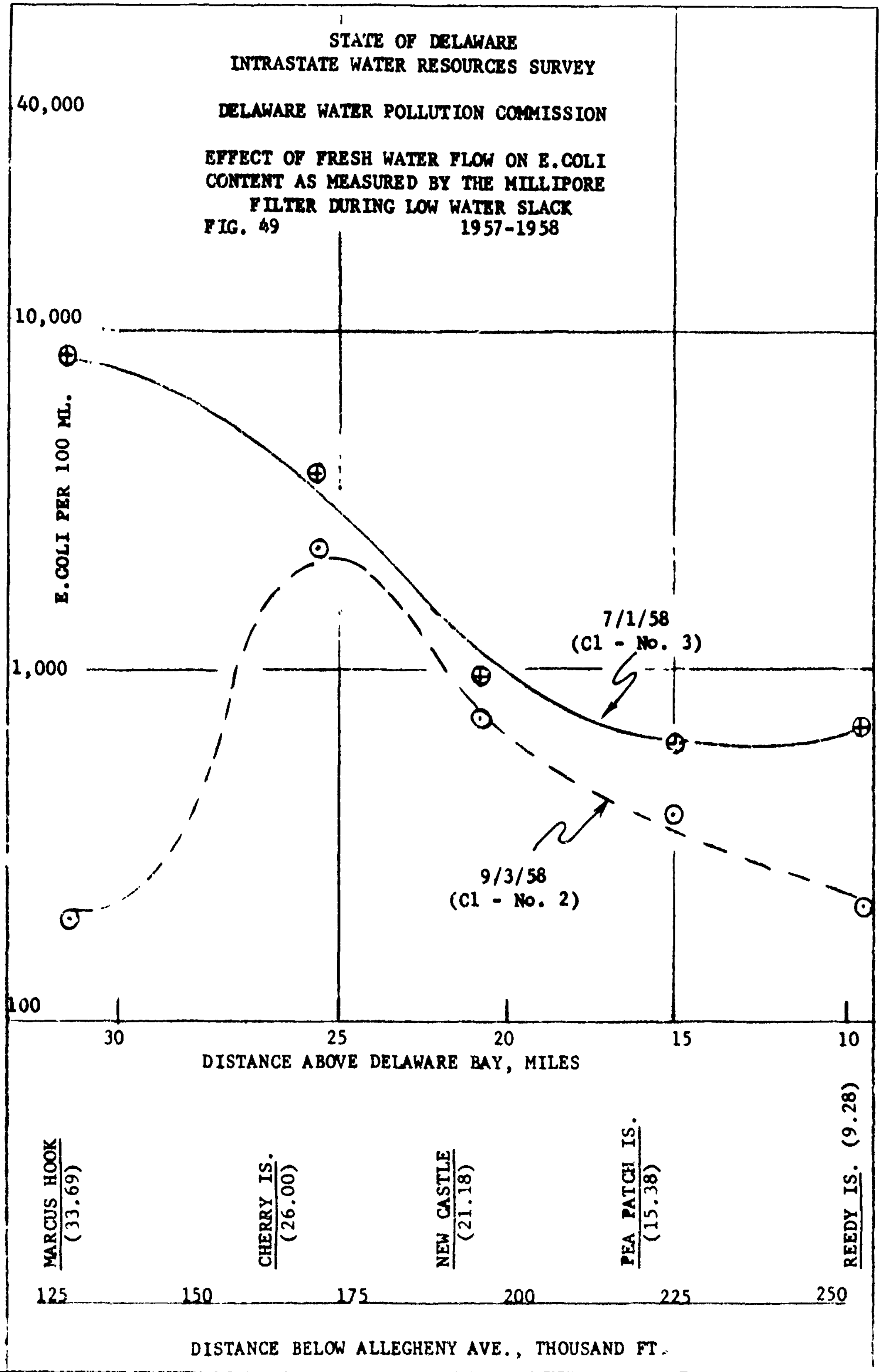


STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

EFFECT OF FRESH WATER FLOW ON E.COLI CONTENT AS MEASURED BY THE MILLIPORE FILTER DURING LOW WATER SLACK

FIG. 48 1957-1958



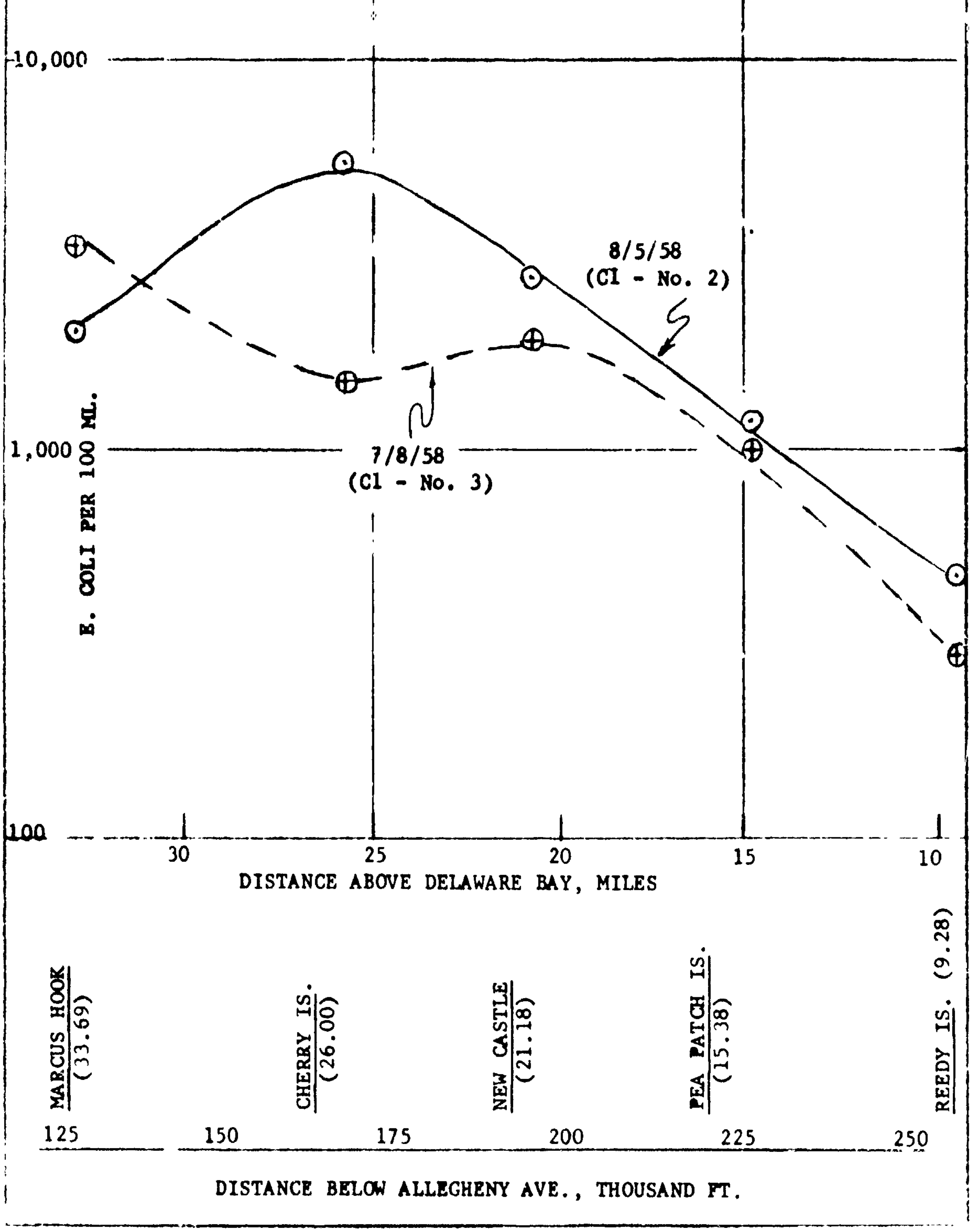
STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
DELAWARE WATER POLLUTION COMMISSION
EFFECT OF FRESH WATER FLOW ON E.COLI CONTENT AS MEASURED BY THE MILLIPORE FILTER DURING LOW WATER SLACK
FIG. 49
1957-1958
40,000
10,000
1,000
100
E.COLI PER 100 ML.
7/1/58
(Cl - No. 3)
9/3/58
(Cl - No. 2)
30
25
20
15
10
DISTANCE ABOVE DELAWARE BAY, MILES
MARCUS HOOK (33.69)
CHERRY IS. (26.00)
NEW CASTLE (21.18)
PEA PATCH IS. (15.38)
REEDY IS. (9.28)
125
150
175
200
225
250
DISTANCE BELOW ALLEGHENY AVE., THOUSAND FT.

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY

DELAWARE WATER POLLUTION COMMISSION

EFFECT OF FRESH WATER FLOW ON E. COLI CONTENT AS MEASURED BY THE MILLIPORE FILTER DURING LOW WATER SLACK

FIG. 50 1957-1958



SECTION XX

BOARD OF GAME AND FISH COMMISSIONERS

20.01 INTRODUCTION

A comprehensive report on the projected water needs from the standpoint of fish and game conservation, preservation and utilization necessitates the very careful consideration and the evaluation and the prediction of the following general trends:

Population growth dynamics
Changes in labor patterns
Changes in recreational habits

In an effort to predict that quantity of water necessary to meet recreational needs in the State of Delaware during the next 50 and 100 years, considerable use will be made of projected population figures, as this is probably the fundamental criterion (1) (Note: Numbers in parentheses refer to literature cited; see appendix to this section.) Almost paralleling this will be the working day-working week trend, and as these two will complement each other, recreational needs may not simply change in proportion to population but may multiply many times as the population doubles. The problems involved here between people and fish and game resources are not opposed nor do they necessarily conflict. There is, however, a constant challenge to provide increased recreation in terms of these resources, for the increased number of people, by wise and careful management plans.

The growth of the Delaware River Basin, including all but a small part of the State of Delaware, has in the past and is currently demanding a great deal of attention as one of the most rapidly-growing sections in the country. This expansion has naturally placed more demands and greater responsibility on all agencies concerned with serving the public needs and desires. The annual increased sale of hunting and fishing licenses and migratory waterfowl stamps (Appendix, Exhibits A, B, and C) vividly demonstrate the request of the people that adequate hunting and fishing lands and waters be provided and maintained by the Board of Game and Fish Commissioners. The task of satisfying these demands will require careful planning integrated with the planning of all the other agencies concerned with water usage, and the planning will have to begin immediately.

Various fish and game management techniques have evolved which will permit more sport on smaller land and water areas. However, this in itself will not fully counteract the increasing competition for lands and waters by other interests. Therefore, it is concluded that it will be necessary to strive for the preservation of many more public hunting and fishing areas, the more efficient utilization and increased multiple use of existing ones during the next 100 years. We will have to provide facilities for three times as many people by the year 2010 and six times as many by 2060, since we can assume that the license sales will increase in proportion to the population.

Progressive labor trends with shorter working days and weeks, more holidays and longer vacations have given more people added opportunity for recreation. A continuation of these patterns must be further assumed. Improved and expanded transportation facilities permit the public to travel farther from their homes for their leisure time. Thus many of the recreational facilities in this area, especially the shore areas in southern Delaware, are easily within one day's traveling distance of metropolitan northern Delaware and southeastern Pennsylvania.

Therefore, it can be concluded that it will be necessary to preserve many more areas, to create more efficient use of all areas, and to assume some changes in hunting and fishing habits if we are going to provide facilities for these sports for three times as many people in 2010 and six times as many by the year 2060.

20.02 POWERS AND DUTIES OF THE BOARD (2)

The present 3-man Board of Game and Fish Commissioners was established in 1911. This Board was given the following powers and duties:

a. The Board shall protect, conserve and propagate all forms of protected wildlife of this State, and enforce by proper actions and proceedings the law relating thereto. The Board shall authorize such studies as are necessary to the work of the Board, and shall collect, classify, and preserve such statistics, data and information as in its discretion will tend to promote the objects of this title.

b. The Board shall employ wardens and other necessary employees and shall fix the salaries of all such employees, who shall have the power to arrest in the same manner provided in subsection (d) of this section, and for the same purpose therein described, and be subject to and serve during the pleasure of the Board.

c. The Board shall establish such departmental bureaus or divisions and shall authorize the employment of such competent employees as may be deemed necessary.

d. The Board shall prescribe the form of licenses issued by it; shall collect all fees for licenses issued by it and all fines and forfeitures imposed for violations of the game and fish laws of this State; shall have authority to arrest without warrant for all violations of the game and fish laws of the State in order to carry out the provisions thereof.

20.03 MANAGEMENT OF FRESHWATER FISHERIES

Proper management of fishing lakes and ponds has become closely allied with public ownership. Almost without exception, Delaware's ponds were built to furnish water power for various types of mills. At the time most of them were built the problem of hydraulics was not understood or was not taken into consideration as well as it is today. Poor material was often used in the construction of the dikes and in many cases trees were permitted to grow on them. Water control structures were built so that water levels could be held to permit operation of the mill and were designed with the idea that someone would always be on hand to raise or

lower the gates as the need for water power or the amount of rainfall dictated. In more recent years most of these mill owners have converted their equipment to operate electrically, finding this power cheaper and more reliable. Many of the mills have been abandoned altogether and with this decreased need and use of water power the gates have, in many cases, been left unattended or have been removed so that attention was unnecessary. This has resulted in either a decided lowering of the water level or, in many instances, washouts and the total loss of the impoundment. The lowered water level, resulting from the owners raising the gates permanently so they need not be attended, has a decided detrimental effect on the pond and fish life. The large area of shallow water that remains is very favorable to the growth of aquatic vegetation which soon takes over the pond. When this happens the fishing and the fish suffer. The natural loss of fishing area is a serious problem as well.

Thus the policy of the Commission has been to attempt to get these waters and water control structures in public ownership before public monies are used in maintenance. Long range plans involve the creation of permanent spillways with drawdown facilities on all ponds. This will eliminate the need for continual surveillance of gates and will decrease the ever-present danger of washouts. This will also permit the maintenance of greater depth of water at stabilized levels.

a. Maintaining suitable environment for fish life. In order to preserve the many benefits that fish and wildlife resources make available to the peoples in the State of Delaware at the present time, certain minimum water quantities at a quality suitable for the reproduction and growth of fish and wildlife should be attained. The basis of fish and game management, as related to providing these recreational and commercial assets, is determined by the creation and maintenance of suitable environment in which the fish and/or wildlife can grow suitably, reproduce successfully, and be harvested in edible or usable condition.

(1) Lakes and ponds. The inland lakes and ponds within this State need clean, well-oxygenated water for fish survival and growth. There are several problems interrelated with this maintenance. Water must be kept at least at its present level and preferably at a higher level in the future. By improving land management practices in the watersheds leading to the impoundments excessive runoff during flash rains can be reduced. This decrease in siltation would minimize the rate of buildup from the bottom. Preliminary observations of the quantity of this siltation in Haven Lake, located on the Kent-Sussex County line at Milford, Delaware, indicate that silt has been deposited at the rate of approximately one-quarter inch per year over most of the lake bottom. Within the next 100 years costly dredging will have to be undertaken to remove the silt. Such procedure and costs will be dependent upon the availability of small portable type dredges that will operate efficiently in shallow small mill ponds. At present-day costs of dredging it is conceivable that this could be carried out for approximately $200 per acre of bottom.

(2) Streams. The quality of water necessary for fish reproduction and growth varies with the species of fish and with the entire food chain associated with a particular species. The streams of the Christina watershed, specifically White Clay Creek, Pike Creek, Mill Creek , Red Clay

Creek and the Brandywine River (Exhibit D - Appendix) have the potentiality for management of cold water stream fish species (3). The most desirable of such fish are fresh water trout and smallmouth bass. Although it is well recognized that trout management hinges on stocking, experiences have shown that the trout fishermen will pay a large share of stocking costs by purchasing an additional license specified for that purpose. Such stockings are planned so that the streams are in their best condition: medium stream flow, temperatures below 68° F., and dissolved oxygen content above 5 parts per million.

The minimum quantity and/or oxygen requirements needed for fish survival are still not fully understood. It has been pointed out by several research workers that the effects of oxygen depend upon several other factors and it is not safe to assign any definite oxygen limit without considering these (4). The list of minimum oxygen requirements (Table 1) is included to show that the formerly accepted 5 parts per million oxygen tolerance level, so long used as a reference may be too high, especially in reference to the warm water species such as largemouth bass and bluegills.

These streams are presently being managed at only a fraction of their potential. The increased stocking of fish over a longer period of time and over more miles of streams could conceivably take care of six times as many fishermen as they do now. With stream improvements made possible by better treatment and waste disposal, the entire length of Red Clay Creek and White Clay Creek downstream from Newark could be managed for either trout or smallmouth bass. Very little active fisheries management has been carried out on the Brandywine River in Delaware. As the quality of the Brandywine continues to improve it will be able to support greater resident populations of fish and it would be entirely suitable for an extensive "put and take" stocking program. With the ability to fully utilize these streams it should be possible to furnish this type of fishing to 5,000 to 6,000 anglers. The proximity of these streams to heavily populated New Castle County further enhances their recreational value and practically insures a maximum usage of all facilities.

b. Principal uses of our fresh water ponds and streams. The primary and principal function of our ponds and many of our fresh water streams has been one of recreation. The present demand from fishing, boating, and other water activities is at a alltime high and this demand dictates that these areas continue to be used for this activity. The tremendous increase in sporting activity is demonstrated in Exhibit B (Appendix) by the number of fishing licenses sold. According to recent figures released by the Coast Guard (5) there are now approximately 7 million pleasure boats in use in the United States and this number is continuing to increase. This is approximately one for every 24.5 persons. Although there is no accurate estimate for the number presently in use in Delaware, it is reasonable to assume that on the basis of our population there are over 16,000 in this State. The Outboard Boating Club estimated that by the end of 1957 there were 14,000 outboard motors in use in Delaware. This information is indicative also of the boat trailers and accessories, gasoline, oil and the many other marine products sold throughout this basin. The United States Department of the Interior (6) reported in 1955 that fishermen spent about $2 billion per year in their sport, and

TABLE 1
MINIMUM OXYGEN REQUIREMENTS OF CERTAIN
SPECIES OF FISHES (3)

Species	Oxygen Requirement in ppm	Authority
Brook trout (*Salvelinus fontinalis*)	1.1	Jahoda (1947)
Atlantic salmon (*Salmo salar*)	2.2	Lindroth (1949)
Largemouth bass		
(*Micropterus salmoides*)	2.3	Moore (1942)
	0.6	Cooper & Washburn (1949)
	0.38	King & Smith (1947)
Northern Pike	2.3	Moore (1942)
(*Esox lucius*)	0.3-0.4	Cooper & Washburn (1949)
	1.5	Moore (1942)
	0.3-0.4	Cooper & Washburn (1949)
Black Crappie (*Pomoxis nigromaculatus*)	1.4	Moore (1942)
Pumpkinseed	0.9	Moore (1942)
(*Lepomis gibbosus*)	0.3-0.4	Cooper & Washburn (1949)
Bluegill	0.8	Moore (1942)
(*Lepomis macrochirus*)	0.6	Cooper & Washburn (1949)
above	0.56	King & Smith (1947)
Black bullhead	0.3	Moore (1942)
(*Ameiurus melas*)	0.2-0.3	Cooper & Washburn (1949)
Golden Shiner	0.0*	Moore (1942)
(Notemigonus crysoleucas)	0.2 below	Cooper & Washburn (1949)

*Not measurable.

waterfowl hunters about $20 million. Many people are benefiting directly from the recreational assets, and indirectly from the revenue derived in pursuit of and in the actual recreation. The demand for residential sites on the shores of stable water areas is tremendous and increasing at a rapid rate. There is presently considerable competition for the purchase of lakes and lake shore properties between private and public agencies.

c. Irrigation. Irrigation during several dry summers in the past has seriously depleted the water quantity in several of Delaware's fresh water ponds. Silver Lake at Dover was lowered by irrigation practice 4 to 5 feet during the summer of 1954. Water being lowered to such an extent will have serious effects on the reproduction and survival of fish if lowered beyond that depth in which spawning takes place. Largemouth bass, bluegill and common sunfish spawn in shoreline water of 1 to 3 feet in depth. Although the bass spawns earlier in the year, April and May, and at a time ordinarily preceding the dry season, the other species will spawn later, even through June and July and are thus susceptible to the effects of drawdowns. Any practice which is capable of lowering the water levels in the lakes and ponds or decreasing the flow in a stream to the point of adversely affecting reproduction or growth of fish or by making the area unattractive and undesirable so that these products cannot be utilized must be prohibited if we expect them to retain their present recreational benefits.

It is apparent that there will continue to be an ever-increasing demand for water for irrigation. Although at certain times there will be excess impounded recreational waters which can be used, the predicted quantities will not be available. Therefore, additional supplies for this particular consumptive use should be sought.

d. Future program for public fishing. The restoration, maintenance and acquisition of waters will be a major part of the future development program of the Game and Fish Commission. This will involve the complete restoration of 45 to 50 ponds, averaging 30 surface acres in area, at an approximate cost of $1.5 million dollars. In addition to the construction of new ponds, those presently operating will need to be maintained at a cost ranging from $200 to $300 each per year (Exhibit E - Appendix). A continued program of the development and maintenance of public access facilities on all fresh waters will permit increased usage. By the year 2060 it is conceivable, however, that the fisheries resources within the State will be developed to their capacity and these facilities will be inadequate to accommodate the increased number of sportsmen. When this happens the increased expansion of marine facilities may take up some of the overflow.

20.04 THE COASTAL MARSHES

The coastal marshes of Delaware, comprising approximately one-eighth of the State's area, are among the most productive in the country. These wetlands, because of the role they play as breeding, migrating and wintering grounds are a distinct factor in the overall management of waterfowl in America and especially along the Atlantic flyway. The value of these marshes to fish, wildlife and ultimately to recreation is great. The role they play as nursery areas for commercial fish and shellfish has

a decided impact on populations throughout the entire Delaware River estuary. It is established that these areas are the prime producers of nutrients, especially phosphorus. Although specific published data are lacking on the extent of this value, it is recognized that the nutritional value of the marsh water and especially the bottom muds is high. In addition to the utilization by various organisms in these areas, the flushing action of the tides certainly contributes to the overall food chain in the estuary by the supplementation of nutrients thus produced.

An inventory conducted by the Department of the Interior, Fish and Wildlife Service (7) reports the following:

"The wetlands in the State of Delaware are of prime importance to the waterfowl populations of the Atlantic Flyway in that not only are they excellent feeding grounds for birds on migration routes but they are, in mild winters, of equal importance as wintering grounds. The production of waterfowl, while not as important as migration or wintering use, is still of such quantity that, on a unit basis, would compare favorably with better known breeding grounds far to the north."

This survey further classified the marshes assigning the following categories:

Type 1 - Soil waterlogged and often covered with as much as one foot of water. Vegetation of trees such as red maple, ash, and willow. This type is important as a nesting and feeding area to the wood and black ducks when it borders open water.

Type 2 - Shallow fresh marshes. Similar to inland waters in physical characteristics, but borders coastal marshes where at high tide it is covered with as much as six inches of water. In Delaware, the giant reed, Phragmites communis, is common in this type. Other plant species are bulrush, threesquare and cattail. Where the reed is not too dense, it is important as cover for migrating and nesting ducks and as a feeding ground.

Type 3 - Deep fresh marshes. Soil covered at average high tide with as much as three feet of water. This type contains such vegetation as wildrice, bulrush and pickerelweed. Of high value as feeding and nesting grounds for ducks.

Type 4 - Salt flats. This type occurs in Delaware coastal saline marshes only as small basins, usually less than 50 feet in diameter. It is not common and the total acreage in the State is estimated at about 100 acres. Vegetation is sparse or patchy and is made up of such species as salt-grasses, glasswort, and fleabane. It is not of significant importance to waterfowl.

Type 5 - Salt meadows. Although the soil of this type is waterlogged it is only covered by the storm or other higher-than-average tides. The vegetation is largely salt-meadow cordgrass with patches of saltgrass and in the fresher parts, threesquare and fleabanes. This type is of value to waterfowl if it contains ponds and potholes. However, in Delaware,

practically all of this type has been ditched for mosquito control and has little value.

Type 6 - Regular flooded salt marshes. The soil of this type is covered at average high tide with as much as three feet of water. Vegetation is mainly saltmarsh cordgrass. Used very much by feeding ducks and geese particularly where ponds containing eelgrass and wigeongrass are present.

Type 7 - Sounds and bays. For the purposes of this inventory, open salt water type is divided into two parts. Type 7 is the area exposed at mean low tide and Type 19 P is the open water seaward from the mean low tide. This type is of negligible value to waterfowl in Delaware. State biologists estimate that there are about 400 acres of Type 7.

On the basis of this study the wetlands were evaluated first for their waterfowl value and secondly for their general value to other forms of wildlife. Exhibit F (Appendix) locates the areas evaluated for waterfowl geographically, while Exhibit G (Appendix) evaluates and locates these areas in respect to furbearers.

The marshes throughout the country have been disappearing at an alarming rate. Delaware has been no exception. Increased demands for industrial and residential sites, dredging of shipping channels, filling marsh areas and increased water uses have resulted in an upsurge in dollar real estate value of those remaining. Table 2 illustrates the per-acre market value as determined by actual price paid during the last 6 years. Although there is a considerable range of values placed on wetlands, the overall higher-priced land is in New Castle County where there is greater demand for the marshes by non-wildlife interests.

For the past 9 years the Game and Fish Commission has carried out extensive waterfowl inventories during the migrating season. The average total number of waterfowl present at the time of the counts is shown in Table 3. Since 1955 average populations have continued to decline slightly; however, the November 1958 count indicates some increase over similar counts during the past 3 years.

TABLE 2

COST PER ACRE OF MARSHLAND PURCHASED BY THE BOARD OF GAME AND FISH COMMISSIONERS DURING THE PAST SIX YEARS*

Area	Site Name	Acres	Total	Cost per Acre
2	Augustine Beach	73.5	$25,000	$340.14
3	Woodland Beach	2765.0	62,500	22.60
3	Little Creek	1921.0**	85,250	44.37
4	Primehook	625.0	50,000	80.00

* These areas contain some upland although they are primarily marshes.

** Final purchase pending.

TABLE 3

WATERFOWL MIGRATIONS AND WINTERING POPULATIONS IN DELAWARE (8)

Average number of waterfowl counted by months, 1950-1955

September	10,000
October	30,000
November	72,000
December	85,000
January	70,000
February	62,000
March	47,000

The Game and Fish Commission has undertaken an extensive program for the preservation and improvement of wetlands in the State. In the next 50 to 100 years it is conceivable that all the marshes will be classified in the highest category as a result of public demand for hunting areas. It is the objective of the Game and Fish Commission to double the quantity of marsh land that is presently in public ownership. Exhibit H (Appendix) shows the amount of marsh now in public ownership and the wetland areas proposed for public ownership in the next 100 years. In addition to this acquisition program, private marsh owners will be encouraged to improve and preserve their marshes. One way of doing this will be to point out to the owner that a marsh can justify itself and to demonstrate how this can be accomplished. Steenis, et al. (9), have the following to say about this program:

"One of the objectives of this report is to show that marshes justify themselves. Another has been to describe methods of increasing wildlife crops from marshes so that the landowner, sportsman, and others may receive more from them. Since the improvements should be guided by a ratio of benefits received to money and effort spent, marsh values and management costs are of interest to the operator.

"Marsh values that can be easily measured in terms of money include revenues from muskrat harvest, rental fees from blinds, and income from turtles and fish. On a well-managed marsh these benefits are often in excess of $200 per acre.

"Values which are less easily expressed but which may outweigh the others are those concerned with the recreation and particular kind of beauty associated with productive marsh lands. One may watch a flock of ducks settle into the reeds at twilight, observe egrets feeding, or measure the flight of geese along a gun barrel. According to individual taste, these experiences can be deeply rewarding, but they have no price tag.

"Marsh improvement costs vary with the site and method of management It is well to remember that both waterfowl and muskrats are attracted by favorable combinations of food and cover. Development of small areas which supply missing parts of these favorable combinations can make much larger areas highly attractive. Wherever possible, the cost should be reduced by taking full advantage of terrain and installations constructed by other

interests but which, with slight modification, will aid management. Roads, railroad embankments, and dredging spoil can make excellent dikes. Tidal gates constructed for drainage can be modified so that, when it is desirable, water levels can be regulated. Upland drainage, which often goes directly to streams, ponds, and other bodies of water can be made to seep through marshes, thus increasing their fresh water supply."

20.05 THE ROLE OF ALLIED DEVELOPMENT IN GAME AND FISH MANAGEMENT

a. Mosquito control. Mosquito control practices should consider wildlife as studies indicate that in many cases the mosquito problem can be more effectively and more permanently solved by moderate changes in water level and by the impoundment of water. Philen and Charmichael (10) state that:

"Water management in one form or another has been practiced from the very beginning of 'preventive' mosquito control measures. It constitutes the basis for all control planning, and any adaptions, whether it be drainage, water level fluctuation of impounded waters, diking and dewatering, diking and flooding, or hydraulic filling, are for the sole purpose of preventing the development and emergence of those lowly insects that plague mankind and hinder the economic development of the country."

Any area should be studied for the best method of control, realizing the values of fish and wildlife before such control measures are initiated. Indiscriminate ditching and the destruction of nursery and nutrient areas for fish and shellfish, resting and nesting areas for waterfowl, and habitat for furbearers will have to be curtailed if the needs for recreation are to be approached. Continued effort should be directed toward biological control of pest mosquitoes. Diking of water has been tested by a number of entomological studies. Philen and Charmichael (10) make the following summary concerning this:

"On the basis of data and observations obtained from the two diked and flooded areas, plans were made for diking and flooding hundreds of additional acres last year. Work proceeded rapidly according to plan except that some areas were not flooded after completion of the dikes. Personnel were not available to carry out as complete observations as would be needed for drawing definite conclusions as to the benefits, if any, obtained from areas diked but not flooded. A detailed study will be made this year on these and other such projects. The observations that were made seemed to indicate that very little breeding occurred within these diked but unflooded areas. There are at least three logical reasons why this actually may have occurred: (1) there were numerous permanent bodies of water within the dikes that supported a large minnow population; (2) spring tides were prevented from intermittently flooding the marsh about every 3 weeks; and (3) the rainfall was probably a little under normal.

"On those areas that were initially flooded after the mosquito breeding season began, it was necessary to apply larvicides to control the first brood of mosquitoes emerging from eggs deposited in the marsh areas. This was foreseen and expected. No trouble was experienced subsequent to the first brood, and it is believed that this can be avoided in the future

when it is possible to take advantage of the high fall tiedes to flood the area initially.

"The observations made last summer in the diked and unflooded areas, although certainly not adequate, have led us to revise the working procedure formerly followed in the construction of diking and flooding projects. Since it is possible that data obtained during this next season may show there is very little additional benefit to be obtained through construction of a dike on the landward side of the marsh, this portion of the work is being deferred pending the obtaining of additional data. Work is continuing on the construction of dikes on the shoreward edge of the marsh as the first phase of this work. The dike is tied into high ground at intervals in order to form cells which may later be of value if flooding is indicated. Evidence to date seems to indicate that the shoreward dike will keep spring tides from intermittently flooding the marsh and that rains will not present a serious problem. If such is proven not to be the case, then the landward side dike will be constructed and the area flooded. During the past fiscal year ending on September 30, 1955, a total of 8,162 acres had been diked at a cost of $6.12 per acre. This is only a fraction of the cost that would have been incurred for ditching, or filling, on an acreage basis.

"As has been previously pointed out, there is insufficient data available at present to answer many questions that arise concerning the effectiveness of this type of work. In addition to the observations that will be made in areas previously constructed, observations will be made on a specially selected area of about 50 acres on the west coast. Two acres will be diked and compared with 3 adjacent control areas. The occurrence of breeding will be correlated with tide and rainfall in the hopes of establishing a definite relationship in the diked areas as compared with the natural marsh control areas."

Darsie and Springer (11), in a study of breeding in impounded and natural marshes in Delaware, state, "Where practical, a combination of the flooding and drawdown systems would appear to be most advantageous in minimizing the mosquito nuisance and in providing conditions at least partly favorable for waterfowl. Under such a program a peak water level would be attained in the spring. This would be kept high as long as possible but would be gradually lowered during the summer when precipitation is reduced and the evaporation rate is high, still leaving a central flood area. Reflooding of exposed shore line could be undertaken after the mosquito control season, or as near to its termination as possible. This water-management plan would favor both submerged aquatics and emergent food and cover plants, as well as many kinds of small animal life, and should provide conditions attractive to the greatest variety and numbers of waterfowl, herons, shorebirds, and many other marsh birds.

"Under either the permanent-flooding or drawdown system, or a combination of the two, mosquito-eating fishes comprise an important part of the control program. Ordinarily, species such as the mummichog and variegated minnow are included in a tidal area when it is diked off. If fish are absent, it is recommended that the above and other important species, including the gambusia (Gambusia affinis), striped killifish (Fundulus Diaphanus), and other killifishes be introduced. It is important in a drawn-down

impoundment to maintain fish so that they can combat mosquito breeding caused by reflooding. For this purpose, sump areas below the general level of the pond bottom, which still retain water during the drawdown period, are needed. The construction of borrow ditches and potholes, as previously described, would serve this purpose and assist these predators in reaching mosquito-breeding sites."

From the results of these studies, it is indicated that a combination of diking and chemical control have definite possibilities of being the most economical and permanent methods.

Plans were initiated during the past year to impound 400 acres of lowlands for mosquito control in a critical mosquito breeding area in Kent County southeast of Dover. Due to the inability to obtain land and water easements to effect this work the project was discontinued. However, alternate sites are being explored for the development of this type of control. Such a cooperative effort involving various agencies with the idea of mutually beneficial results, in this case mosquito control and wildlife management practices, is a sound and feasible program.

b. Highway construction. Cooperative efforts with the State Highway Department in their routine highway maintenance and development have been effective and should be expanded. Road building with thoughts to planning for wildlife can, and has in the past, been of great benefit to wildlife resources in the State. With adequate planning, marshes and inland ponds often can be improved in conjunction with bridge construction and the installation of dams and tidegates with considerable benefit to hunting and fishing interest.

Red Lion Creek, the Thousand Acre Marsh, Port Penn Marsh, Augustine Creek, and Woodland Beach are examples of this type of improvement. In these cases about 2,000 acres of marsh were impounded creating fresh water stabilized conditions which have proven a great benefit to muskrats and waterfowl. Studies in Delaware (9) have shown that on marshes that have regulated water control perennial plants important as muskrat foods can be encouraged. Such plants as cattail (Typha spp.), threesquare (Scirpus olneyi), saltmarsh bullrush (Scirpus robustus), and softstem bullrush (Scirpus validus) will make an abundant supply of preferred food available to the muskrat. Annual plants can be encouraged to volunteer and spread on marshes with water control features. Wild millet (Echinochloa crusgalli) and annual smartweeds (Polygonum spp.) are examples of these that are extensively utilized by waterfowl. Darsie and Springer, in a study at Bombay Hook National Wildlife Refuge east of Smyrna, Delaware, compiled Table 4 on the comparison of use by water birds of impounded and unimpounded areas (11).

c. Dredging Channels. Dredging of shipping channels and basins should be done considering any possible detriments or benefits to fish and wildlife that might occur in the operations. Such beneficial possibilities should be incorporated into the planning of future projects to insure maximum recreational and commercial fisheries consideration. Areas for disposal of the dredgings should be studied so that the most valuable fishing and spawning areas are not destroyed, and where possible the spoil should

TABLE 4

NUMBERS OF WATER AND WETLAND BIRDS UTILIZING UNIMPOUNDED AND IMPOUNDED STUDY AREAS DURING 1954-55 and 1955-56 (11)

	Unimpounded				Impounded			
	Bear Swamp		Check Area		Raymond Pond		Shearness Pond	
Birds	1954-55	1955-56	1954-55	1955-56	1954-55	1955-56	1954-55	1955-56
Loons and Grebes		10	3	12	2,700	740	1,760	540
Double-crested Cormorant					16	30	4	11
Herons and Bitterns	940	370	210	220	9,280	2,720	5,490	5,300
Glossy Ibis					55		4	3
Whistling Swan					710	250		9
Geese (total)		50			316,330	315,748	78,010	117,980
Canada Goose		50			315,270	315,740	77,960	117,850
Snow Goose					890			30
Blue Goose					170	8	50	100
Surface-feeding Ducks (totals)	31,920	43,060	4,015	8,630	146,220	192,220	196,450	212,930
Mallard	2,550	3,960	120	260	13,830	79,450	59,440	49,210
Black Duck	23,000	27,740	3,700	7,930	20,730	15,810	58,610	23,480
Gadwall	320	1,690	100	160	10,040	12,750	4,860	6,870
Pintail	1,680	400			32,770	62,640	29,860	103,790
Green-winged Teal	3,330	6,170			18,060	2,120	8,260	7,030
Blue-winged Teal	600	570	65	120	6,620	1,120	1,590	950
American Wigeon	50	890			31,750	18,240	25,530	
Shoveler	390	1,640	30	160	12,310	790	8,090	980
Wood Duck					110		210	100
Diving Ducks (total)		15			1,900	967	603	314
Redhead					100	22		
Ring-necked Duck					220	550	350	230
Canvasback					720	65		
Lesser Scaup					190		8	13
Common Goldeneye					120			
Bufflehead					460	40	65	6
Ruddy Duck		15			90	290	180	65

TABLE 4, continued

NUMBERS OF WATER AND WETLAND BIRDS UTILIZING UNIMPOUNDED AND IMPOUNDED STUDY AREAS DURING 1954-55 and 1955-56 (11)

Birds	Unimpounded				Impounded			
	Bear Swamp		Check Area		Raymond Pond		Shearness Pond	
	1954-55	1955-56	1954-55	1955-56	1954-55	1955-56	1954-55	1955-56
Mergansers (total)	60	76		7	8,590	1,924	307	618
Hooded Merganser	60	30		7	590	180	70	60
Common Merganser		35			8,000	1,730	230	550
Red-breasted Merganser		11				14	7	8
Hawks and Eagles	280	140	200	140	690	480	600	700
Rails and Coots (total)	1520	1,170	2,459	2,6[illegible]	830	820	90	430
King Rail	610	350	15	[illegible]	680	610	10	330
Clapper Rail		2,060	2,030					
Virginia Rail	550	500	210	190		45		
Sora	120	90	4		150	160	80	100
Black Rail	240	230	170	170		5		
Gallinule						14	250	24
American Coot			4		8,730	5,540	27,130	6,140
Shorebirds (total)	5,620	4,470	390	544	75,400	27,790	5,350	6,610
Common Snipe	960	470		14	360	100	90	50
Other Shorebirds	4,660	4,000	390	530	75,040	27,690	5,260	6,560
Gulls and Terns	40	190	50	19	25,200	12,620	390	1,870
Belted Kingfisher	90	55	55	60	150	35	100	40
Total	40,470	49,906	7,386	12,252	596,801	562,598	316,538	353,519

be moved to less productive areas. Other offshore areas will need to be determined by marine studies. In some areas it is feasible that these materials should be used in building dikes and levees which would be of benefit to wildlife (Appendix, Exhibit I).

The proposed area immediately south of the Cheseapeake and Delaware Canal is suggested in conjunction with the dredging of an anchorage in that vicinity. The remaining proposed shoreline areas are suggested as disposal areas for channel dredging. The Little Creek site proposal is to dump soil along sections of both banks of the stream creating stabilized water over a considerable area creating an improved waterfowl habitat. Other such areas may practically be suggested along Delaware's shoreline south of Little Creek if for any reason dredging is to take place near the shore. With population growth the economic feasibility of these efforts will increase.

d. Pollution control. Continued decrease in pollution from industrial wastes and from erosion of top soil must be stressed. The Board of Game and Fish Commissioners was, prior to 1947, specifically charged with pollution control. There was little control by this body due to lack of funds, qualified personnel, and facilities to cope with complicated industrial, municipal, and interstate problems. This, in part, led to the creation of the Delaware Pollution Control Act which was passed in 1949. This Act formed a Commission financed and empowered to progress with this ever-increasing problem. The Game and Fish Commission accepts its role in this by virtue of membership on the Water Pollution Commission.

e. Filling. Efforts must be made to prevent the filling of better waterfowl and muskrat marshes for residential and industrial sites. Planning and zoning should insure preservation of the only remaining natural areas that are available for recreation and commercial fishing. The recent report of the New Castle County Planning Commission proposes such planning that would, in effect, be in accordance with recreational planning by the Board of Game and Fish Commissioners. It is highly desirable to obtain and maintain such facilities near the most densely populated section of the State.

20.06 MARINE SPORT FISHING IN DELAWARE

The estimated total number of people sport fishing in Delaware's salt waters, total man-hours and total fish caught during the 14-week period from 29 May through 3 September, 1955, were determined (13). This information was ascertained by using the figures from 21 airplane counts of people fishing from 13 June through 31 August. With this information and the percentage of people fishing (from the various fishing pressure patterns) at the times the counts were made an estimate of the average number of people fishing per day was computed. Multiplying this average by the total days, 98, gave an estimate of total people fishing for each type of fishing. Total man-hours and fish were computed using this total estimate of people and the recorded numbers of man-hours and fish from the various interview sheets. Results of the 1955 fishing season are summarized in Tables 5 and 6.

TABLE 5

THE STATE RESIDENCE OF PEOPLE SALT WATER SPORT FISHING IN DELAWARE - 1955

Type of Fishing	Location	Delaware %	Pennsylvania %	Other %	No. of Interviews
Party	Bowers Beach	21.4	70.4	8.1	98
	Mispillion	37.5	50.0	12.5	8
	Lewes	0	78.1	21.9	32
	Indian River	3.5	71.8	24.5	57
Row Boat	Lewes	26.4	69.0	4.6	751
	Slaughter Beach	57.1	42.9	0	
	Kitts Hummock	62.9	29.5	7.6	
	Woodland Beach	37.3	54.7	8.0	
	Port Penn	72.3	20.1	7.6	
	Indian River Bay and Rehoboth Bay	12.0	74.4	13.9	332
Surf		19.7	55.3	25.0	87
Jetty		19.1	52.1	28.8	435
Bank-Bridge		64.1	34.7	1.2	237
Average		33.3	54.1	12.6	

TABLE 6

ESTIMATED TOTAL NUMBER OF PEOPLE SPORT FISHING IN DELAWARE SALT WATERS, TOTAL MAN-HOURS AND TOTAL FISH CAUGHT - 1955

	Number of People	Total Man-hours	Total Fish Caught	Croaker	Trout
Small Boat, Delaware Bay	71,300	344,000	744,400	608,000	109,500
Small Boat, Indian River Bay and Rehoboth Bay	76,000	379,000	423,000	------	130,000
Surf	39,300	148,400	76,300	8,700	34,900
Jetty	88,600	247,000	67,200	2,100	7,400
Bridge & Wharf	4,400	17,100	16,100	3,600	1,400
Party Boat	61,700	458,600	1,291,700	225,200	120,500
Total	341,300	1,594,100	2,618,700	847,600	403,700

	Flounder	Spot	Sea Bass	Blue Fish	Other
Small Boat, Delaware Bay	14,800	4,400	-----	------	6,700
Small Boat, Indian River Bay and Rehoboth Bay	285,000	------	2,300	------	5,700
Surf	------	------	------	------	32,700
Jetty	46,200	------	9,600	------	1,900
Bridge & Wharf	1,200	------	------	------	9,900
Party Boat	------	------	892,000	54,000	------
Total	347,200	4,400	903,900	54,000	56,900

The dollar value of this activity is difficult to determine. However, conservative estimates placed it at a minimum of $2 million in 1955 (6). With the increase in the use of pleasure boats this figure has undoubtedly gone higher each succeeding year.

A summary of the value of the Delaware commercial fishery is listed in Table 7 (14). The fishery included here indicate the products landed at Delaware ports and include menhaden and shell fish, some of which were caught in the ocean and even beyond the influence of Delaware Bay.

TABLE 7

DELAWARE COMMERCIAL FISHERIES-1955

Product	No. of pounds	Dockside dollar value
Menhaden	307,470,000	4,091,000
Oyster	3,290,000	1,603,000
Bluecrab	2,819,000	253,000
Seatrout	1,579,000	123,000
Other	1,855,000	295,000

Both sport and commercial fisheries will be influenced by changes in salinity and changes in the manufacture and transport of nutrients from the river through the estuary and to that portion of the Atlantic Ocean influenced by this system.

20.07 PRESENT DEVELOPMENT PROGRAM

Wetland development in Delaware at the present consists of the following practices, implemented both by Game and Fish personnel and contractual services.

The following will serve as an outline to the development work presently being carried out by the Game and Fish Commission with department personnel and equipment supplemented by the rental of heavy equipment:

- Upland
  - Ponds
  - Potholes
- Marsh
  - Impoundments
  - Potholes
  - Level ditches
- Millpond Restoration

a. Upland: ponds and potholes. These are developed in inundated areas and vary in size from one-third to three acres and average one acre. They range in depth from 2 to 4½ feet, averaging 30 inches. Department equipment, operating mostly on privately-owned lands, is used for most of this work. Ponds differ from potholes in that larger drainage areas here (up to 70 acres) necessitate incorporation of water control structures; the latter utilize emergency spillways only, because of restricted drainage areas (about 5 acres) and are dependent upon surface drainage for this

water supply. Exhibit H (Appendix) shows those already in existence and although this map does not show the exact location of the proposed development, the general area with an approximation of the quantity is the more important aspect. Extensive field work and planning is necessary prior to the choice of any exact site.

(1) Effects upon drainage. Most of these features are located in natural draws or sinks, where on normal or wet years crops drown out, and are lost to production. Moreover, drainage of many of them is precluded by the cost of ditch construction in relation to the size of the area drained. Hence, the size of the reservoir is made larger, and a more or less permanent pond and fixed field edges established. While these features have no adverse effect upon upland drainage they do effect a local upraising of the water table which will have long term advantages to surrounding areas.

b. Marsh.

(1) Impoundments. Diked-off areas of up to a thousand acres, created by dragline or utilization of existing roads as dikes, with elaborate sluices giving control of water level, flow and salinity is the principal type of marsh impoundment. Examples of these are Augustine Creek and the Thousand Acre Marsh.

(2) Potholes. These are areas of from ½ to 5 acres created by dragline through diking off small coves or digging out the whole pond, with no control structures other than emergency spillways, and varying from fresh to salt. They are designed to stabilize and create a permanent water area. Their primary benefit is to waterfowl.

(3) Level ditching. In areas of open marsh level ditching is constructed to create open water and eliminate short term fluctuations in water level. Such management increases the edge effect thereby increasing wildlife usage. Mathiak (12) states that:

"The benefits to muskrats of level ditches are many. In this portion of the marsh, there often is not enough water to allow muskrats to obtain food throughout critical winter periods. The deep water of the ditches makes it possible for muskrats to obtain food such as submerged aquatics despite thick ice, and the high spoilbanks offer more protection from freeze-outs than the average-size muskrat house. During summer drouth periods when other surface water is not available, the depth of the water in the ditches holds muskrats in a marsh. Furthermore, during flood periods, spoilbanks hold muskrats in the ditched area by offering resting sites, feeding places, and shelter."

(4) Effects upon drainage. Obviously level ditches and marsh potholes have no deleterious effects upon upland drainage. Where level ditching is tied into upland drainage ditches it expedites the flow of water from the latter with beneficial effects to agriculture.

In a marsh impoundment there are normally no adverse effects upon upland areas. However, where water is held high, low-lying peripheral pasturage may be inundated. Here the beneficial effects pertaining to the marsh versus the upland must be carefully weighed. Experience has shown that

management to benefit the former has usually resulted, for an impounded marsh is normally high-grade wetland with revenues to be derived from trapping, hunting, and rental of hunting rights that would more than offset losses involved in flooding such pasturage.

c. Millponds. Reestablishment of millponds lost through lack of dike and gate maintenance or other reasons, by installing new and more efficiently engineered dikes and water control structures, has been discussed previously. By cooperative agreement and action of the State Legislature, Highway Department, Game and Fish Commission, and landowners this restoration is made possible. Exhibit E (Appendix) points out the proposed impoundment program.

(1) Effects upon drainage. Engineering design of millpond water control structures is such that no adverse effects upon surrounding uplands are felt. Moreover, water thus stored has and is being used to irrigate crops, although the legality of this practice under certain conditions is questionable. Certainly unrestricted irrigation from water supplies upon which the present principal use is recreation should be discouraged.

With the predicted increases in population growth of the State, additional water recreation areas will need to be created. To keep pace with the growing demand, approximately 2,000 acres of new inland fresh water fishing area will be needed. In the event of a shorter work week and increased individual recreational demand, more than the predicted acreage will be necessary.

Continued pollution abatement should result in approximately ten additional miles of streams being made suitable for fish in New Castle County. This would approximately double the present available area for stream fishing and other recreation. Adequate plans should incorporate public recreation on large municipal water supplies.

The most promising outlet for increased recreational effort, the Delaware River and Bay, is of paramount importance in planning for the future. Continued efforts in pollution abatement and the insistence on guaranteed minimum flows from upstream impoundments will help to insure that the full potential of this resource may be utilized.

d. Commission's program of public access sites. The program of the creation of public access sites along Delaware's inland and marine waters has been and will continue to be a major activity of the Game and Fish Commission. The State has, to date, constructed 17 of these areas at an average cost of $2,000 each. Approximately 24 more are proposed for development during the next 10 years and as a greater number of these will be on tidal water they will probably cost an average of $4,000 each. The trend in boating and availibility of good fishing areas will determine the program after that date. Areas developed to date and those proposed are shown on Exhibit E (Appendix).

Presently planned and future main stream impoundments on the Delaware River should protect the fishing industry, both sport and commercial, by means of assurance of adequate facilities for migrating fishes.

This will necessitate the installation of adequately designed fishways and fish ladders on all main stream impoundments. In addition, plans for management of the fisheries created in the impounded waters and in the tailwaters below the dams should be incorporated in the preliminary financial aspects of any development.

20.08 SUMMARY

Our present needs indicate that what we have must be preserved and maintained, no more should be destroyed; and, if we are to satisfy the desires of an ever-increasing population, more areas for public use will be necessary. The value of our inland and coastal waters should not be under-estimated and they should be managed and utilized for the greatest benefits to the greatest number of people. They should be estimated at their full recreational values in any priority rating with other uses. Although multiple use of some recreational areas is possible their present and primary use should be respected when faced with the demands from other interests. Fish and wildlife resources in the Delaware Basin are subject to pressures beyond those in any other section of the country and should be given due consideration in situations that would either tend to destroy them or in any development program that would improve them. It is the duty of this Commission to make every effort to preserve the great natural resources of Delaware. With the predicted population it is extremely doubtful if these can be preserved in their present state. It is already a matter of salvage, and to this end we must insist on an effective salvage with proper consideration of the various problems previously mentioned.

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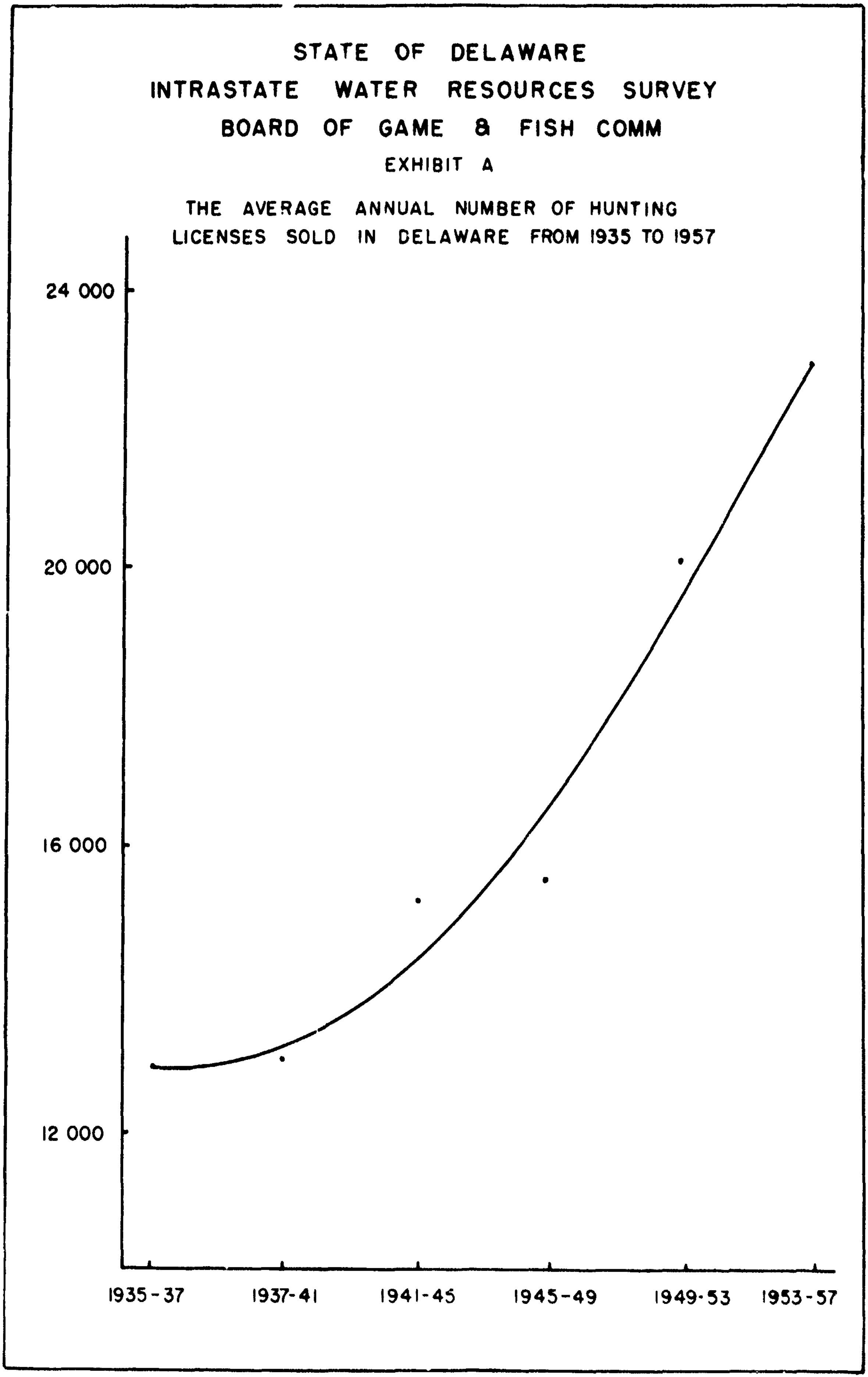

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
BOARD OF GAME & FISH COMM
EXHIBIT A
THE AVERAGE ANNUAL NUMBER OF HUNTING LICENSES SOLD IN DELAWARE FROM 1935 TO 1957
24 000
20 000
16 000
12 000
1935-37
1937-41
1941-45
1945-49
1949-53
1953-57

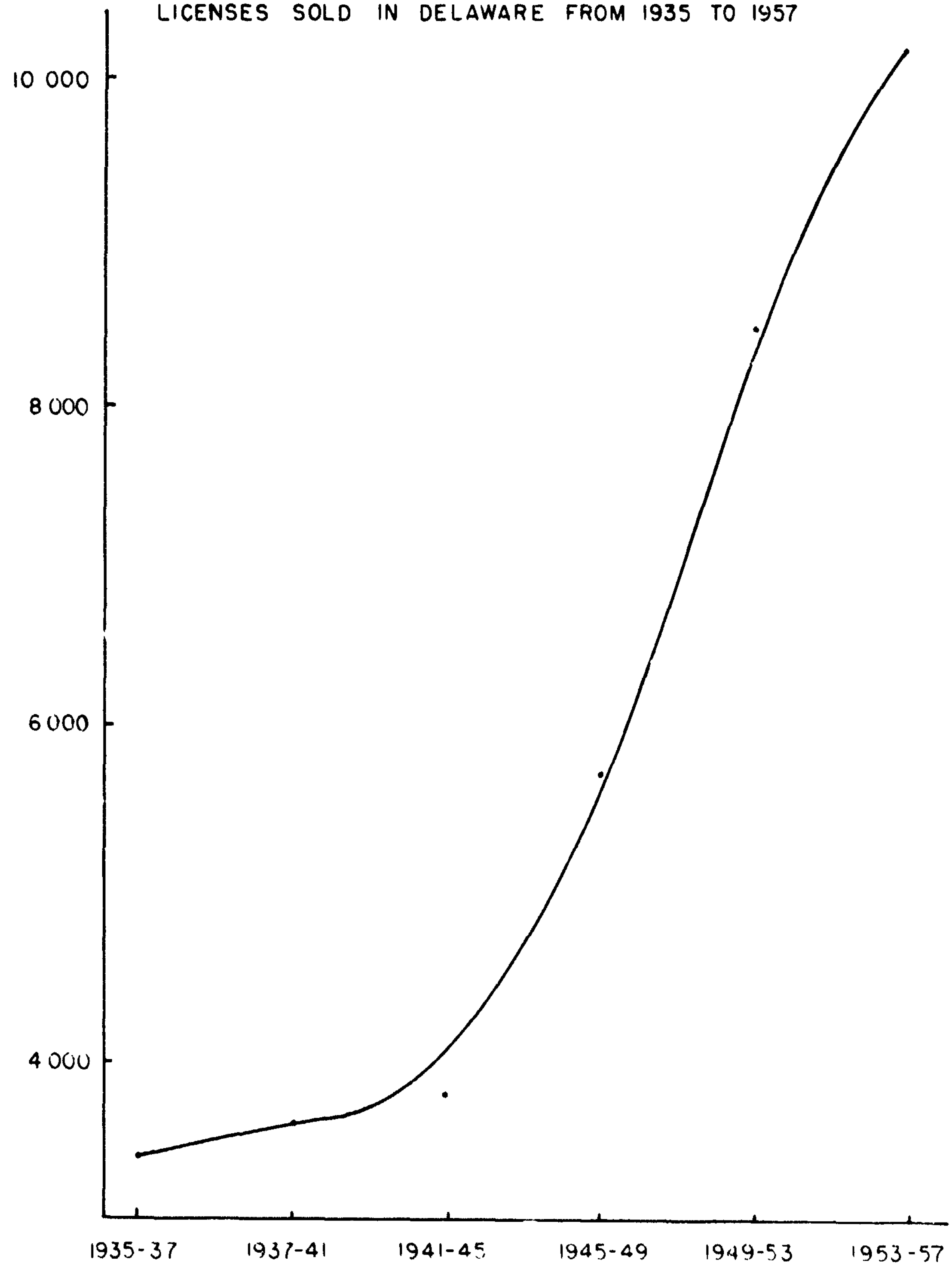
STATE OF DELAWARE

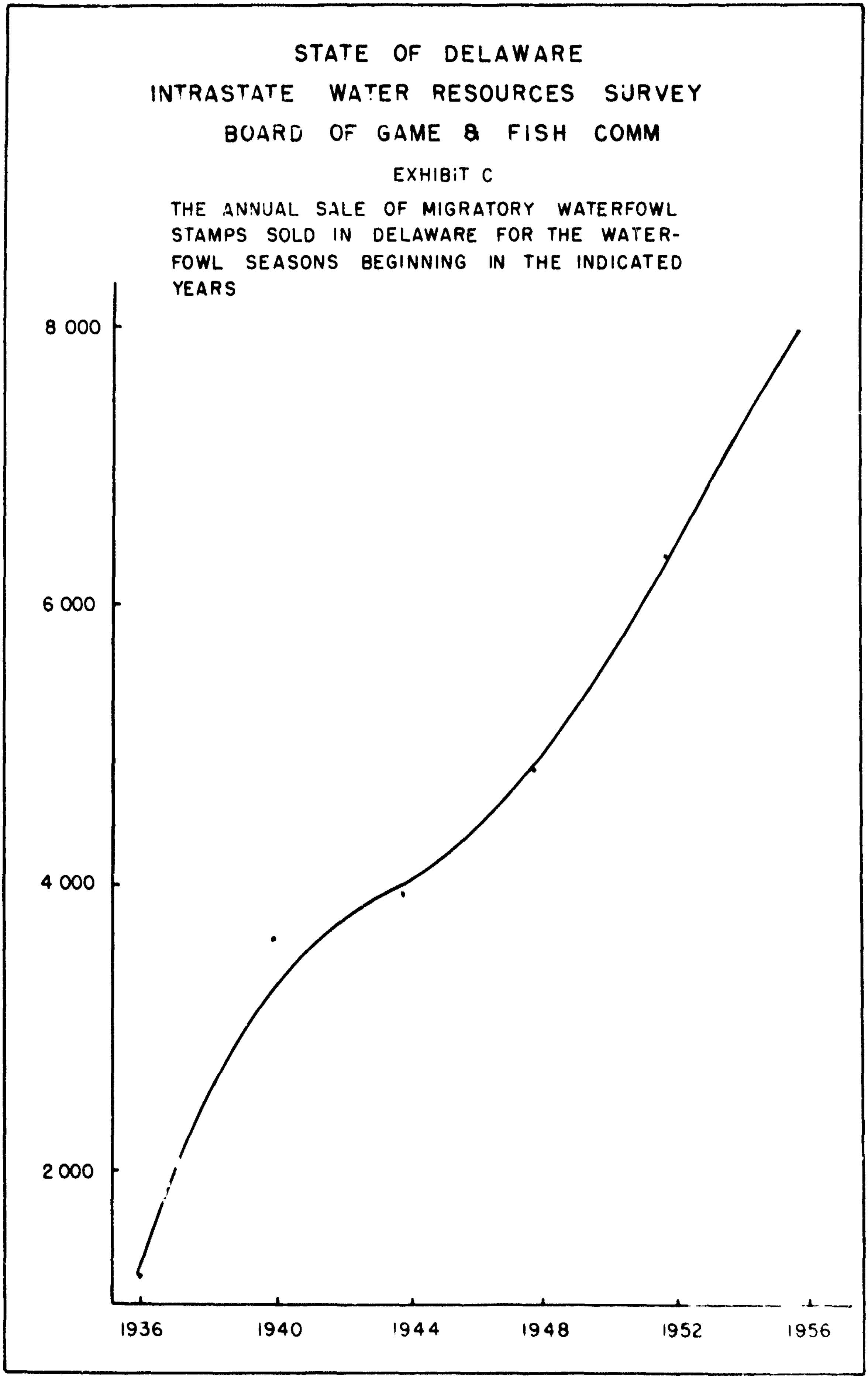
INTRASTATE WATER RESOURCES SURVEY

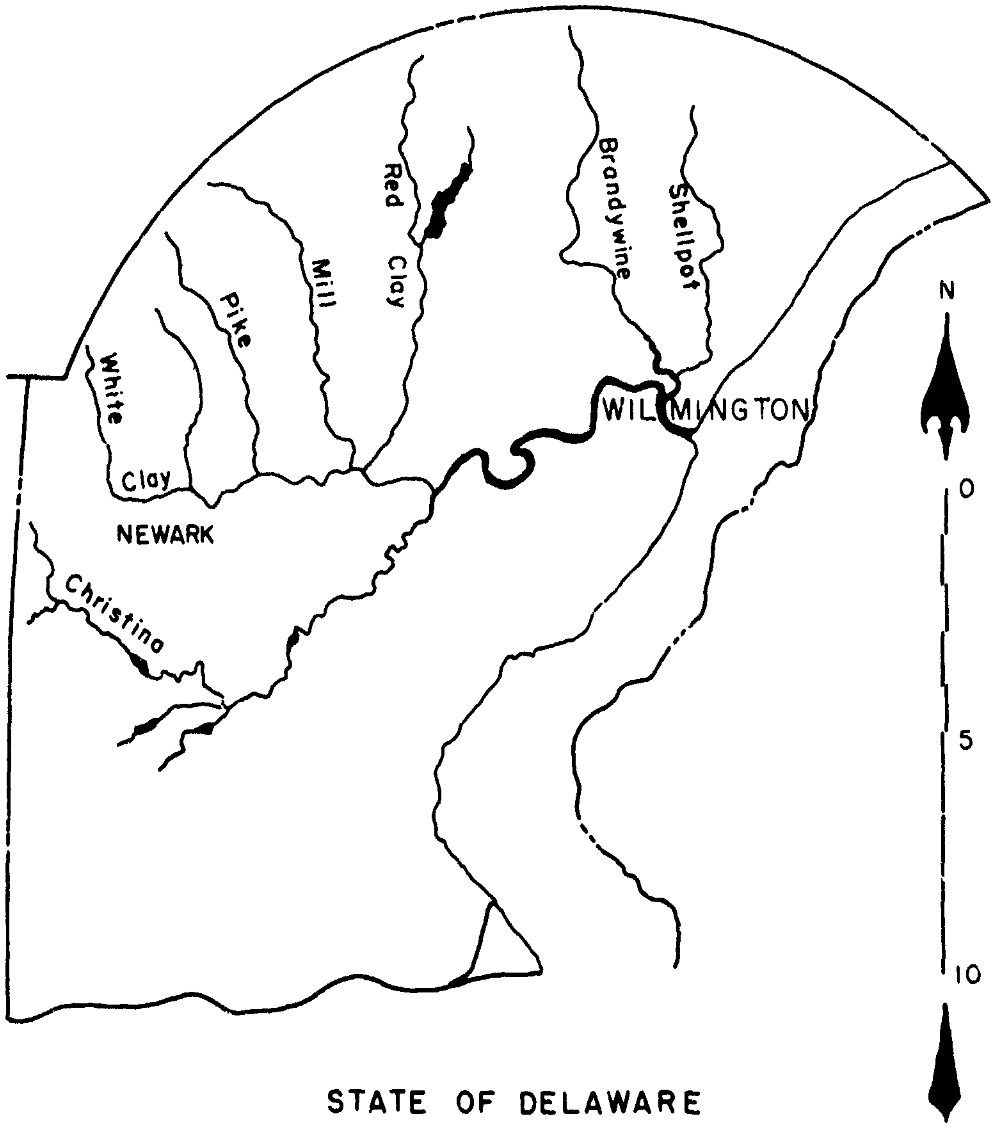
BOARD OF GAME & FISH COMM

EXHIBIT B

THE AVERAGE ANNUAL NUMBER OF FISHING LICENSES SOLD IN DELAWARE FROM 1935 TO 1957




STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
BOARD OF GAME & FISH COMM
EXHIBIT C
THE ANNUAL SALE OF MIGRATORY WATERFOWL STAMPS SOLD IN DELAWARE FOR THE WATERFOWL SEASONS BEGINNING IN THE INDICATED YEARS
8 000
6 000
4 000
2 000
1936
1940
1944
1948
1952
1956



STATE OF DELAWARE

INTRASTATE WATER RESOURCES SURVEY

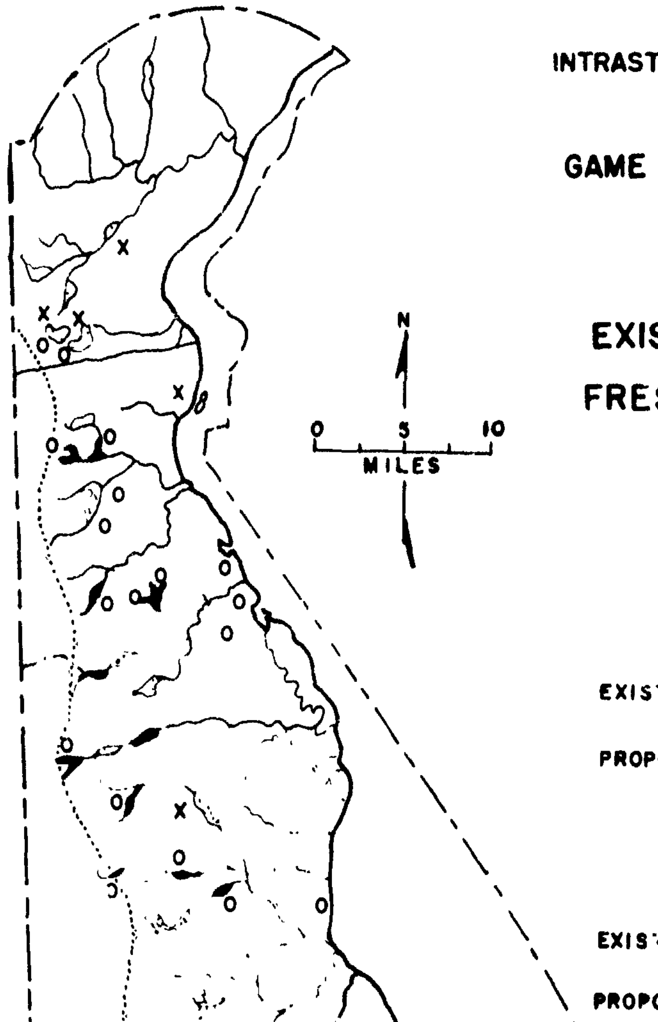
BOARD OF GAME & FISH COMM

EXHIBIT D

THE CHRISTINA WATERSHED

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
BOARD OF
GAME AND FISH COMMISSIONERS

EXISTING AND PROPOSED FRESH WATER FISH PONDS AND LAUNCHING SITES



PONDS

EXISTING

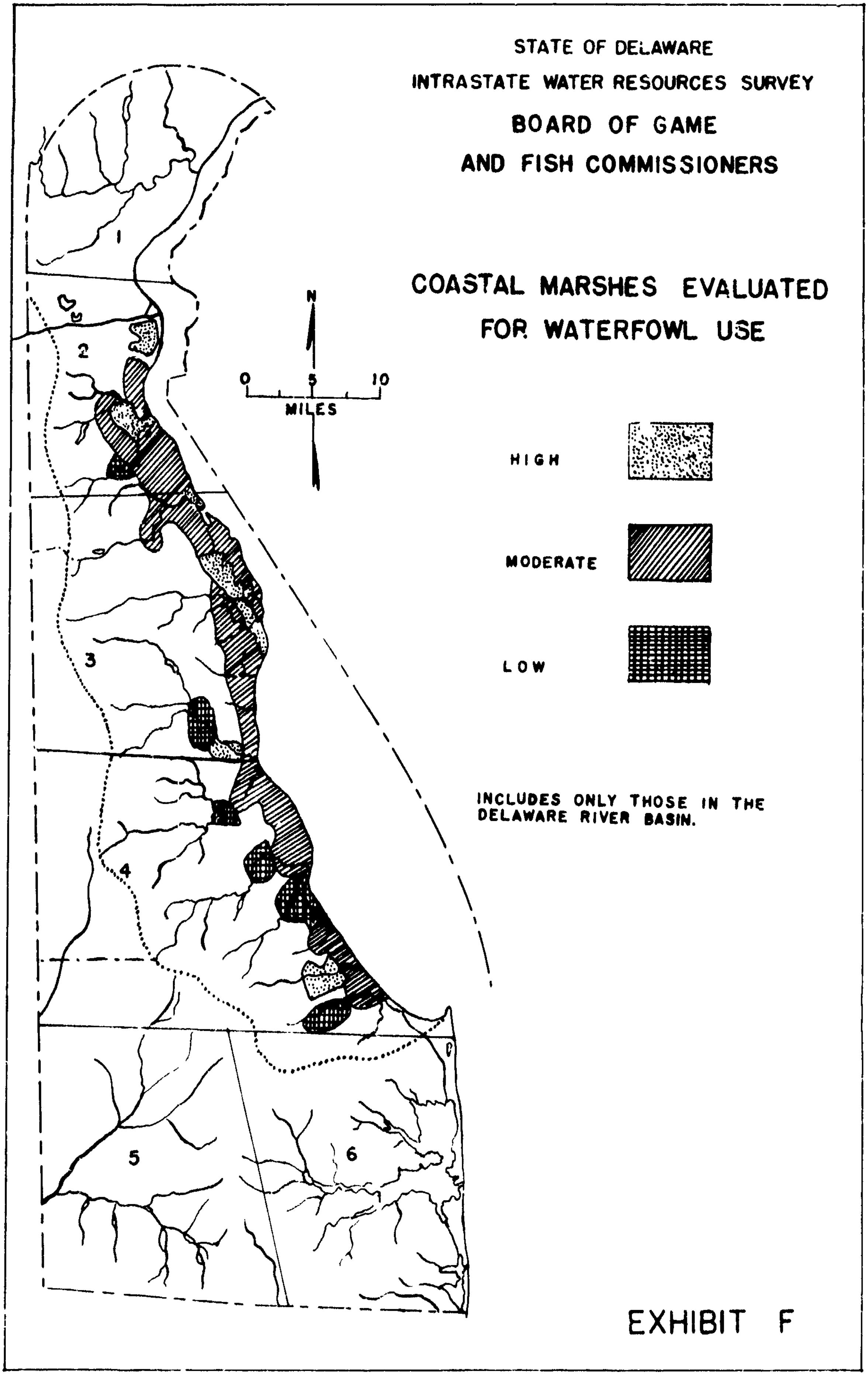
PROPOSED IN NEXT 100 YEARS

LAUNCHING SITES

EXISTING x

PROPOSED IN NEXT 100 YEARS o

EXHIBIT E


STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
BOARD OF GAME
AND FISH COMMISSIONERS
COASTAL MARSHES EVALUATED
FOR WATERFOWL USE
N
0 5 10
MILES
HIGH
MODERATE
LOW
INCLUDES ONLY THOSE IN THE DELAWARE RIVER BASIN.
1
2
3
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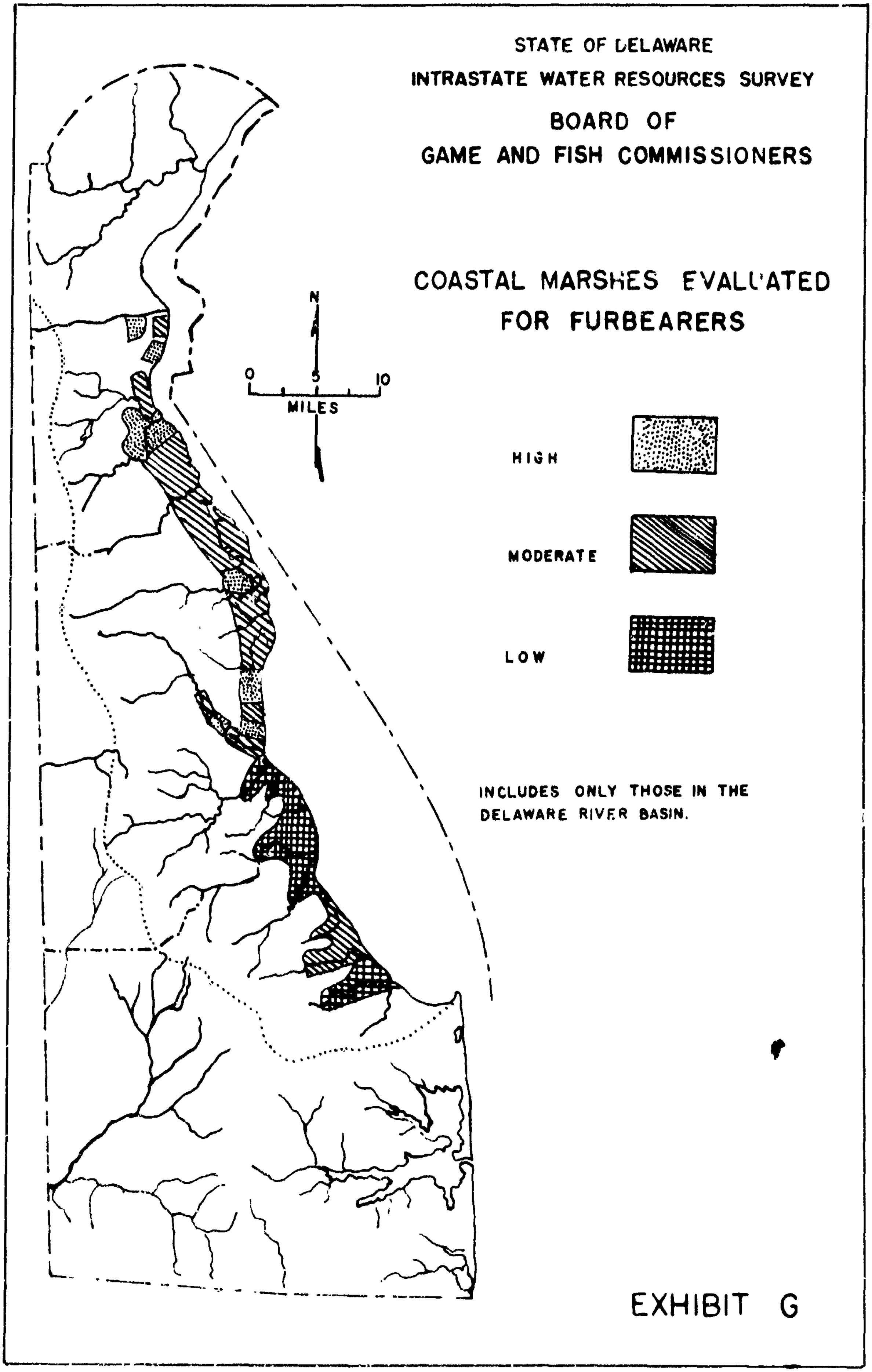
6
EXHIBIT F


STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
BOARD OF
GAME AND FISH COMMISSIONERS
COASTAL MARSHES EVALUATED
FOR FURBEARERS
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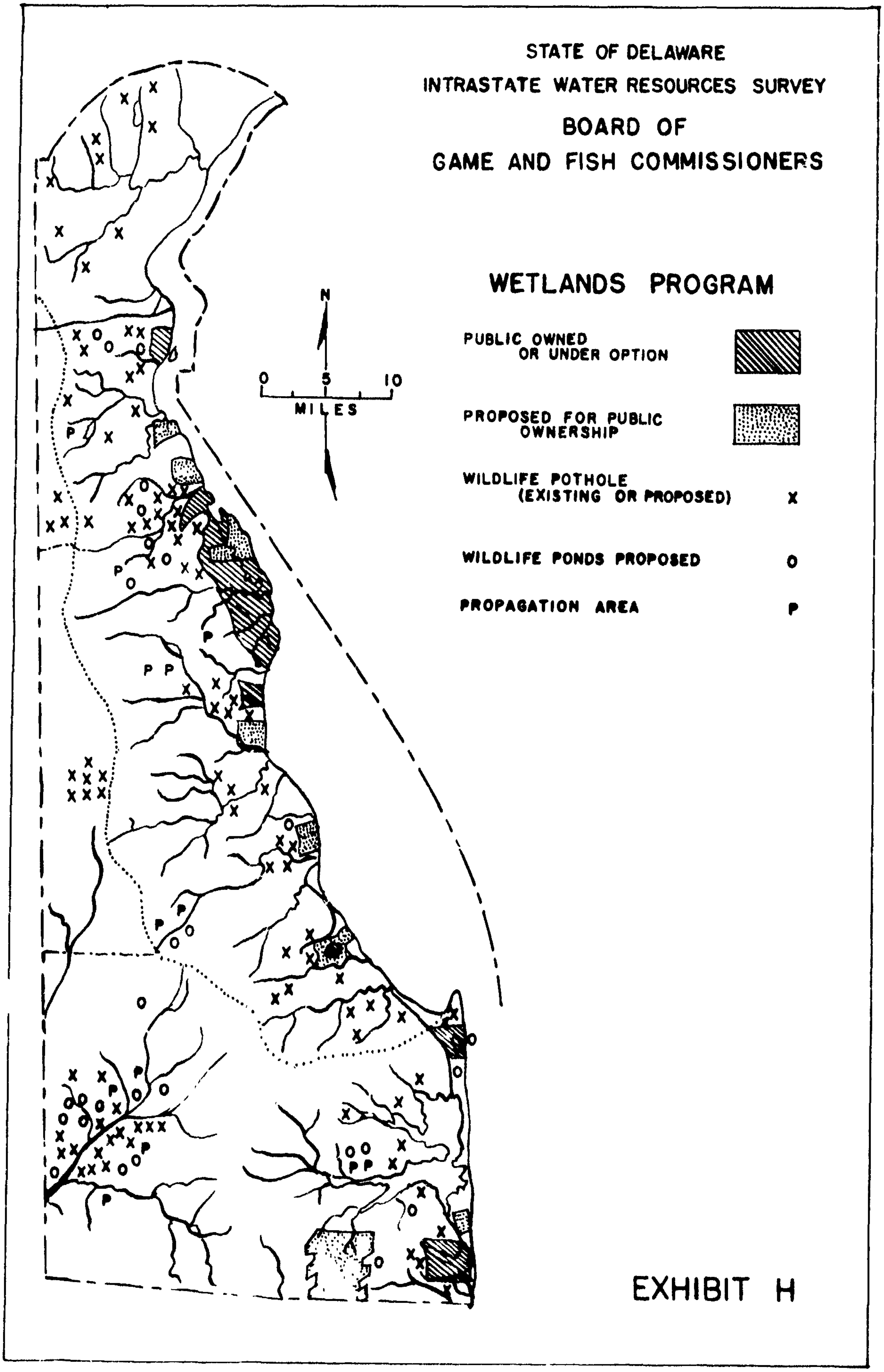
MILES
HIGH
MODERATE
LOW
INCLUDES ONLY THOSE IN THE
DELAWARE RIVER BASIN.
EXHIBIT G


STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
BOARD OF
GAME AND FISH COMMISSIONERS
WETLANDS PROGRAM
PUBLIC OWNED OR UNDER OPTION
PROPOSED FOR PUBLIC OWNERSHIP
WILDLIFE POTHOLE (EXISTING OR PROPOSED) X
WILDLIFE PONDS PROPOSED O
PROPAGATION AREA P
N
0 5 10
MILES
EXHIBIT H

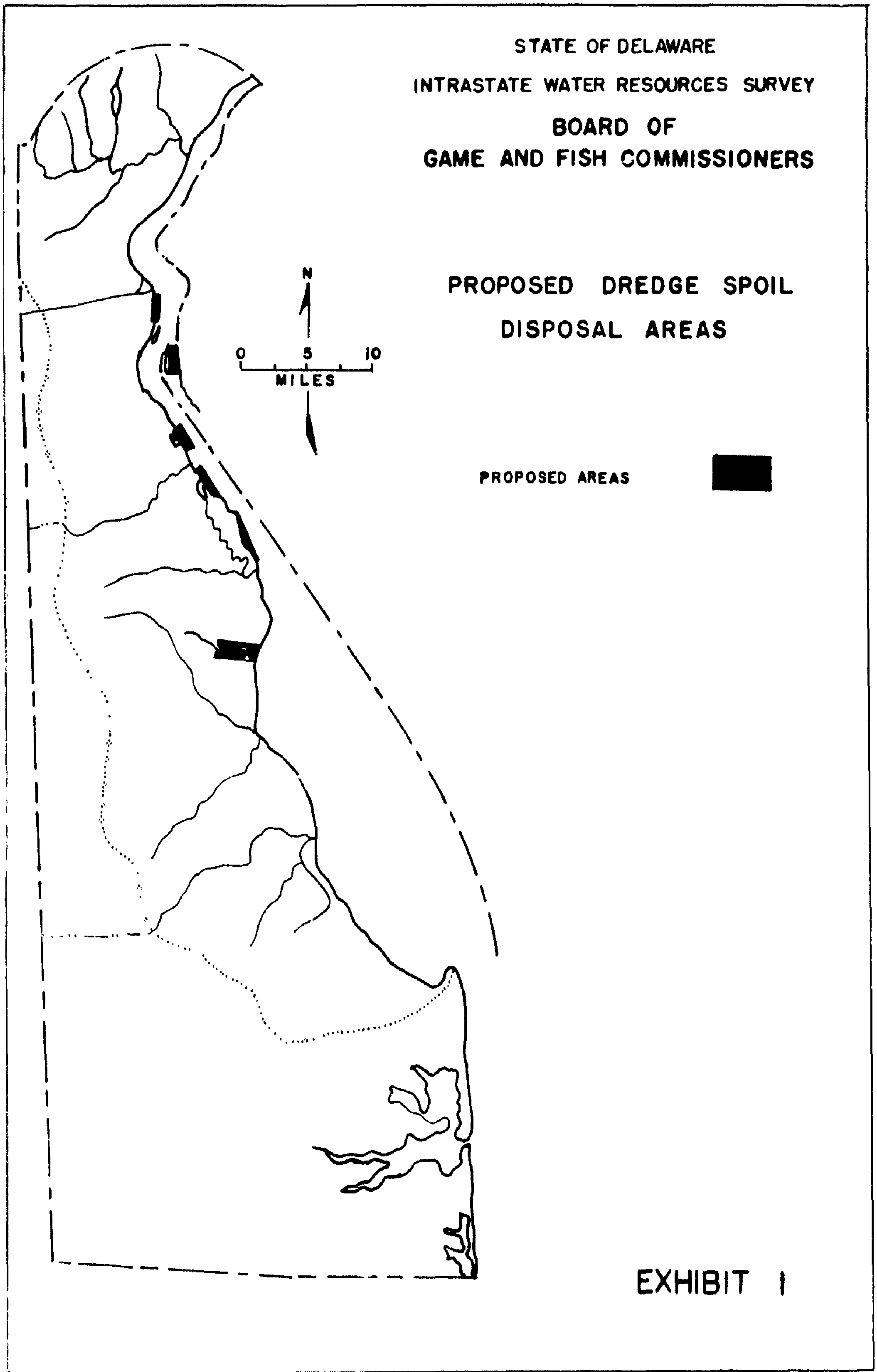

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
BOARD OF
GAME AND FISH COMMISSIONERS
PROPOSED DREDGE SPOIL
DISPOSAL AREAS
N
0 5 10
MILES
PROPOSED AREAS

EXHIBIT 1

SECTION XXI

UNIVERSITY OF DELAWARE
MARINE LABORATORIES

BIOLOGICAL EVALUATION OF THE DELAWARE RIVER ESTUARY

21.01 INTRODUCTION

Prediction of the future water needs of the biota within the Delaware River watershed can be based upon a single principle: the abundant plant and animal populations now living in the watershed area would be adversely affected if the characteristics of the available usable water supply were changed markedly. Since it is also axiomatic that all living organisms were dependent upon water, any marked variations of long duration in the chemical and physical characteristics of that water, either natural or man-made, will determine to a large extent what organisms will survive the changes. These principles apply, with even more restrictions, to the biota in the lower reaches of the watershed, namely, the Delaware River estuary (Figure I). There live and grow multitudinous populations of all kinds of organisms, acclimated through millions of generations to the dynamic present-day estuarine environment.

It can be predicted that an increase in the human population will create greater demands for food and recreational space than are now being exerted upon coastal areas. This pressure for more food and greater use of recreational areas means that the resources of estuaries will be utilized to a much greater extent than at present. Indeed, greater biological production will be needed to meet these needs, and water will be one of the key environmental factors in the plans for increasing food production in our estuaries and increasing the recreational advantages of coastal areas.

It is not the intent of the writer to deal with predictions concerning the future of estuarine life. Much research will be required before tolerances of estuarine organisms can be related to guesses on the possible magnitude and duration of changes in the kind and amount of water that might occur in the estuary. More important, at the present time, is an outline of what is known about biological production in the Delaware River estuary. This outline will form a reference from which comparisons and predictions can be made with more understanding and accuracy, as research data and observations accumulate.

The concept of biological production, which is a central theme of this report, bears a close resemblance to that of industrial production. Instead of reporting upon the number of automobiles manufactured at a certain factory per day, the marine biologist may seek to record the weight of oysters harvested per acre or the amount of microscopic plant life produced per gallon of sea water per day. One objective in productivity studies is to measure the rate at which production occurs. The calculation of this rate serves a useful purpose: it permits the comparison of the production in different marine areas and enables the economic eval-

uation of either an area or a crop, or both. In succeeding portions of this report the concept of biological production will be used to estimate the value of the Delaware River estuary and certain of its crops and areas.

Emphasis is placed also upon the estuary as an environment and upon some commercially harvested estuarine animals. This report is not intended as an exhaustive treatise, but as a document highlighting some of the salient features of what we know about our Delaware coastal areas from the marine biology viewpoint.

a. Acknowledgements. The information contained in this report is based largely upon the collective research experiences of the Marine Laboratories staff and upon the results of special projects undertaken by graduate students. The writer is indebted to his colleagues for the use of their research data and their valuable critiques: Dr. Franklin C. Daiber, Mr. William H. Amos, Mr. Warren S. Schneller, and Dr. Donald P. de Sylva. Mr. Frederick A. Kalber, Jr. has contributed an intriguing hypothesis on a role of tidemarshes in estuarine productivity. The data and discussion on the mysid shrimp, *Neomysis americana*, are based upon the research of Mr. Thomas L. Hopkins. Appreciation is extended to our students for their excellent project reports, without which the writer's task could not have been so easy: Mr. Paul A. Haefner, Jr. (Section 21.03), Mr. Charles M. Bearden (Section 21.06), Mr. Theodore P. Ritchie (Section 21.08 a.), and Mr. Paul W. Hess (Section 21.08 b.).

During the winter-spring period of 1958-1959, Dr. Daiber and his students (Bearden, Haefner, Hess, Hillman, and Kalber) made a pilot study of the Canary Creek Marsh near the Bayside Laboratory at Lewes. This exploratory study was undertaken as the field problem portion of the Fish Ecology course at the University of Delaware. Organized by Dr. Daiber as a cooperative research project, the number of participants enabled a wide attack upon the problem of production in a tidemarsh. Major segments of the research included: hydrography, nutrients, the rooted plant crop, organic detritus, tidemarsh invertebrates, and fishes. Although the data collected and the observations made during this study have not been fully analyzed, a few of the results have been incorporated into this report in Section 21.05 on the significance of tidemarshes in estuarine production.

The content of this report has benefited from the work of the people mentioned above; its organization, and whatever shortcomings are present, are the responsibility of the writer.

21.02 THE UNIVERSITY OF DELAWARE MARINE PROGRAM

a. Establishment. In 1951, during the 116th Session of the General Assembly, an appropriation was made to the University of Delaware to establish "a program of research on past, present, and potential products from the salt waters of the State, of instruction of special students, teachers, and public citizens on the fishery, biology and conservation of aquatic resources, of encouragement of all types of investigation on salt and estuarine waters and their inhabitants, and for provision of advisory assistance to administrative and other agencies concerned with the utilization of marine and estuarine resources." (Laws of the State of Delaware: Volume 48, Chapter 73, pages 155-156.)

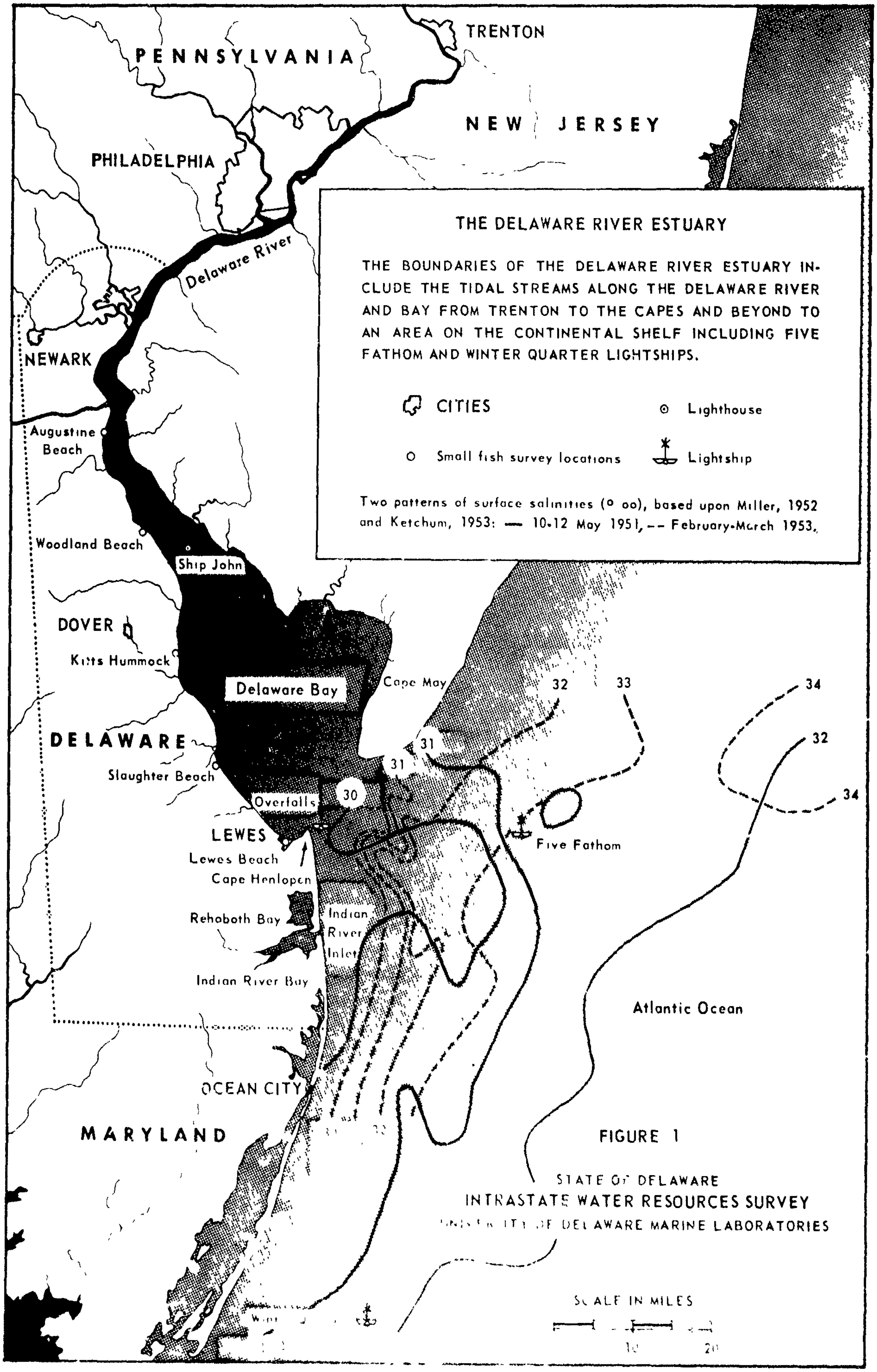


FIGURE 1

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
UNIVERSITY OF DELAWARE MARINE LABORATORIES

A legislative appropriation in 1953 made possible the construction of a permanent field station, the Bayside Laboratory, at Lewes, Delaware. There the M. Haswell Pierce Building was dedicated in 1956. Physical facilities for the marine program are also provided on the University campus in Wolf Hall.

b. Organization. The marine program is an integral part of the Department of Biological Sciences at the University of Delaware. At the University, continuing effort has evolved a program to follow through from research to education to conservation advisement on all matters pertaining to tidewater resources. There has been continuing progress in carrying out this threefold purpose in the law enacted by the General Assembly in 1951. The threefold organization and the scope of the marine program are illustrated in Figure 2. This is the blueprint upon which the entire Marine Laboratories program is being developed.

c. Objectives. The objectives continue as originally and broadly conceived in the establishing legislation. This broad base of objectives is a valuable heritage. It permits the development of a program not hampered by restrictions upon its scope but governed largely by the abilities of its participants. Since it is not now practical to conduct the full scope of possible activities, due both to financial and practical reasons, the responsibility for the kind of program rests largely upon its administrators. In recent years the emphasis has been upon strengthening graduate study, increasing research, and upon communicating the results of the research to the public. Accomplishments within these and other activity areas are documented in a Biennial Report series (1952, 1953-1954, 1955-1956, 1957-1958) published by the Marine Laboratories.

d. Income. The University budget is augmented by contracts with governmental agencies and by research grants from private and national groups. A substantial portion of the income is required to maintain and operate the Bayside Laboratory facilities: the isolated building plant, research equipment, research vessels, docks, bulkheads, and roads. Indeed, if it were not for the additional financing there would not be much research. Expenditures in recent years have varied from $49,000 to $63,000 yearly. This low cost for the marine program contrasts with a minimum annual $10 million fisheries-dependent income in the State of Delaware.

21.03 MORPHOMETRY OF DELAWARE BAY

Morphometry (dealing with the measurement of the topographical features of a lake basin or a stream bed and their included water mass) has developed traditionally as a branch of limnology, the study of lakes and ponds. Since certain fundamental conditions of biological productivity arise directly from the structural relations of bodies of water, it is common procedure to make various measurements of the morphological features of basins to determine the role which the feature may play in biological phenomena. Morphometric studies also provide a convenient quantitative means to compare different bodies of water (Hutchinson, 1957). In this report, morphometric techniques have been used to describe topographic characteristics of Delaware Bay.

PROGRAM OF THE UNIVERSITY OF DELAWARE MARINE LABORATORIES

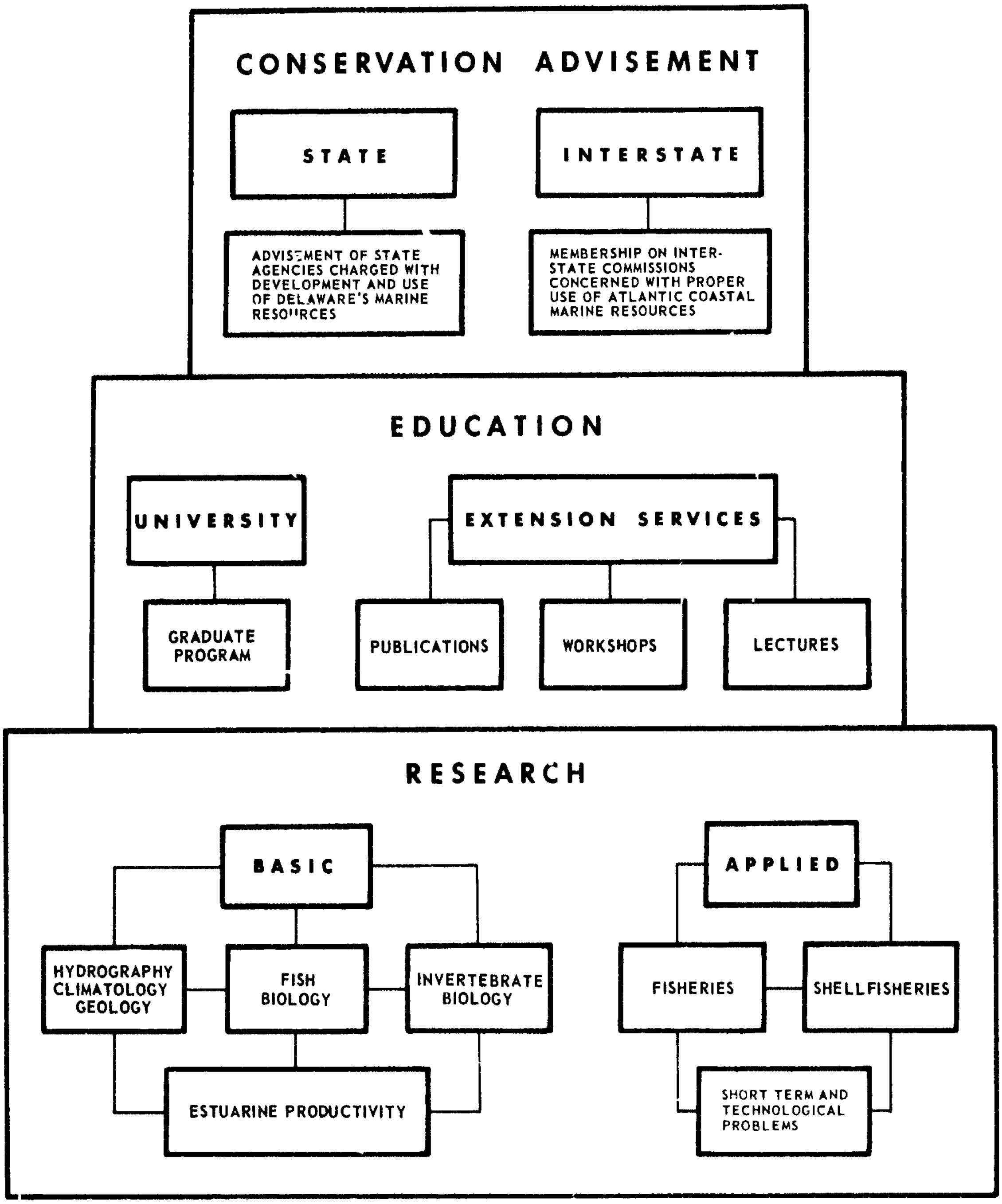


FIGURE 2

STATE OF DELAWARE

INTRASTATE WATER RESOURCES SURVEY

UNIVERSITY OF DELAWARE MARINE LABORATORIES

As far as is known, little or no work had been done on a morphometric analysis of Delaware Bay prior to the present study. The only record in the Marine Laboratories files is an estimate of the depth and volume of the river, bay, and ocean along the coast of Delaware prepared in 1953 by Dr. Eugene L. Cronin, former director of the marine program. This estimate, however, did not include the eastern portion of the bay.

The following material provides morphometric information on Delaware Bay which should prove useful in environmental studies and in evaluating the productivity of the bay.

a. Methods and results. Measurements were made on the U.S. Coast and Geodetic Survey Chart #1218, corrected as of September 13, 1958, were the source of the data reported in this morphometric study of Delaware Bay. The chart is a Mercator projection with a scale of 1:80,000 at Latitude 39°06'.

Various methods, measurements, and calculations described by Welch (1948) and Hutchinson (1957) were used in this analysis. Linear measurements were made with the use of a rotometer calibrated in inches. Areas were determined with the use of a Keuffel and Esser Compensating Polar Planimeter, model #4236, calibrated to read in square inches. All measurements obtained were converted to larger units of area by the use of conversion factors.

Upper and lower boundaries of Delaware Bay were established arbitrarily for the purpose of the analysis as follows:

Upper Boundary. Indicated by a line across the bay from the Smyrna River Light (Delaware) to a point on the New Jersey shore midway between the tower on Arnold Point and the tower at Mad Horse Creek. This point is in the region of Lower Deep Creek.

Lower Boundary. Inland waterway boundary line from Cape Henlopen (Delaware) to Overfalls Lightship to Cape May Inlet (New Jersey).

The data compiled included the following measurements and calculations:

(1) Maximum Length (MxL): 46.7 statute miles; 40.7 nautical miles.

Length of line connecting the two most remote extremities of the bay. In this case, a straight line from the ship channel at the Smyrna River to Overfalls Lightship.

(2) Maximum Effective Length (MxEL): 46.7 statute miles; 40.7 nautical miles.

Length of straight line connecting the most remote extremities of the bay along which wind and wave action occur without any kind of land interruption. Same as Maximum Length in this case.

(3) Maximum Width (MxW): 27.1 statute miles; 23.7 nautical miles.

Length of a straight line connecting most remote extremities of the bay and crossing no land other than islands. It is a line

approximately at right angles to the maximum-length axis. It is a line from Goshen Creek, New Jersey, to Cedar Beach, Delaware.

(4) Maximum Effective Width (MxEW): 27.1 statute miles; 23.7 nautical miles.

Length of straight line connecting the most remote extremities of the width of the bay along which wind and wave action occur without any kind of land interruption.

(5) Mean Width (MeW): 15.3 statute miles; 13.2 nautical miles. The area of the bay divided by its maximum length.

(6) Maximum Depth (MxD): 151 feet; 46.0 meters; 25.2 fathoms. The maximum depth known.

(7) Mean Depth (MeD): 31.7 feet; 5.3 fathoms. The volume of the bay divided by its surface area.

(8) Mean Depth-Maximum Depth Relation (MeD/MxD): 0.21

The mean depth divided by the maximum depth. This is expressed as a decimal value and serves as an index figure which indicates in general the character of the approach of basin shape to conical forms.

(9) Maximum Depth-Surface Area Relation (MxD/As): 0.0035

The maximum depth divided by the square root of the surface area. It is expressed as a decimal value and is an indication of the relation of depth to horizontal extent.

(10) Total Surface Area (As): 720 square miles (statute); 460,000 acres.

The total surface area of the bay. Chart #1218 was divided into 15 sectors to enable easier and more accurate handling of the planimeter. The results for each sector were combined to give the total area. This same technique was applied to the calculation of the areas of submerged contours (Table 1).

(11) Length of Shoreline (Lsh): Delaware, 55.1 statute miles; New Jersey, 73.2 statute miles; Total, 128.3 statute miles.

The length of the shoreline enclosing the bay measured in statute miles.

(12) Shore Development (S): 1.26

The ratio of the actual length of shoreline of the bay to the length of the circumference of a circle the area of which is equal to that of the bay. Methods and formulae used in calculating this data were obtained from Olson (1952).

(13) Volume (V):

Delaware	371,700,000,000	cubic feet
New Jersey	262,100,000,000	cubic feet
Total	633,800,000,000	cubic feet
	4,734,700,000,000	gallons

Determined by computing the volume of each horizontal stratum as limited by the several submerged contours on the hydrographic map and taking the sum of the volumes of all such strata. The depths used were those indicating the mean low water level on the geodetic chart.

(14) Hypsographic Curve: A curve constructed by plotting depth along the ordinate and area along the abscissa. Such a curve provides not only certain elements in the form of a basin, but it also provides a means whereby areas at any depth level may be determined. (See Figure 4)

(15) Profiles: These provide a pictorial representation of the basin configuration along a selected line. The profiles were constructed with a vertical scale of 1 mm equal to 1 foot and a horizontal scale of 1 inch equal to 1.1 nautical mile. The profiles selected were perpendicular to the ship channel with the exception of Number 7, below. The profiles as plotted were:

	Delaware Shore	to	New Jersey Shore
1.	Woodland Beach		Bay Side
2.	Simons River		Ben Davis Point
3.	Little River		Fortescue
4.	Clark Point		East Point
5.	Big Stone Beach		Goshen Creek
6.	Slaughter Beach		Miami Beach
7.	Cape Henlopen		Cape May Point

These profiles are illustrated in Figure 5.

TABLE 1

AREA OF SUBMERGED CONTOURS
(See Figure [illegible])

A1 = Surface to 1 fathom contour depth; A2 = 1 to 2 fathoms; A3 = 2 to 3 fathoms; A4 = 3 to 5 fathoms; A5 = 5 to 10 fathoms; A6 = 10 to 25 fathoms.

(A) AREA OF SUBMERGED CONTOURS IN DELAWARE BAY

Depths	Square Miles (Statute)	Acres (x1000)	% of Total
A1	98	63	13.6
A2	167	107	23.2
A3	147	94	20.4
A4	177	113	24.6
A5	83	53	11.5
A6	48	30	6.7
	720	460	100.0

TABLE 1
(Continued)

(B) AREA OF SUBMERGED CONTOURS IN THE DELAWARE OR WESTERN PORTION OF DELAWARE BAY

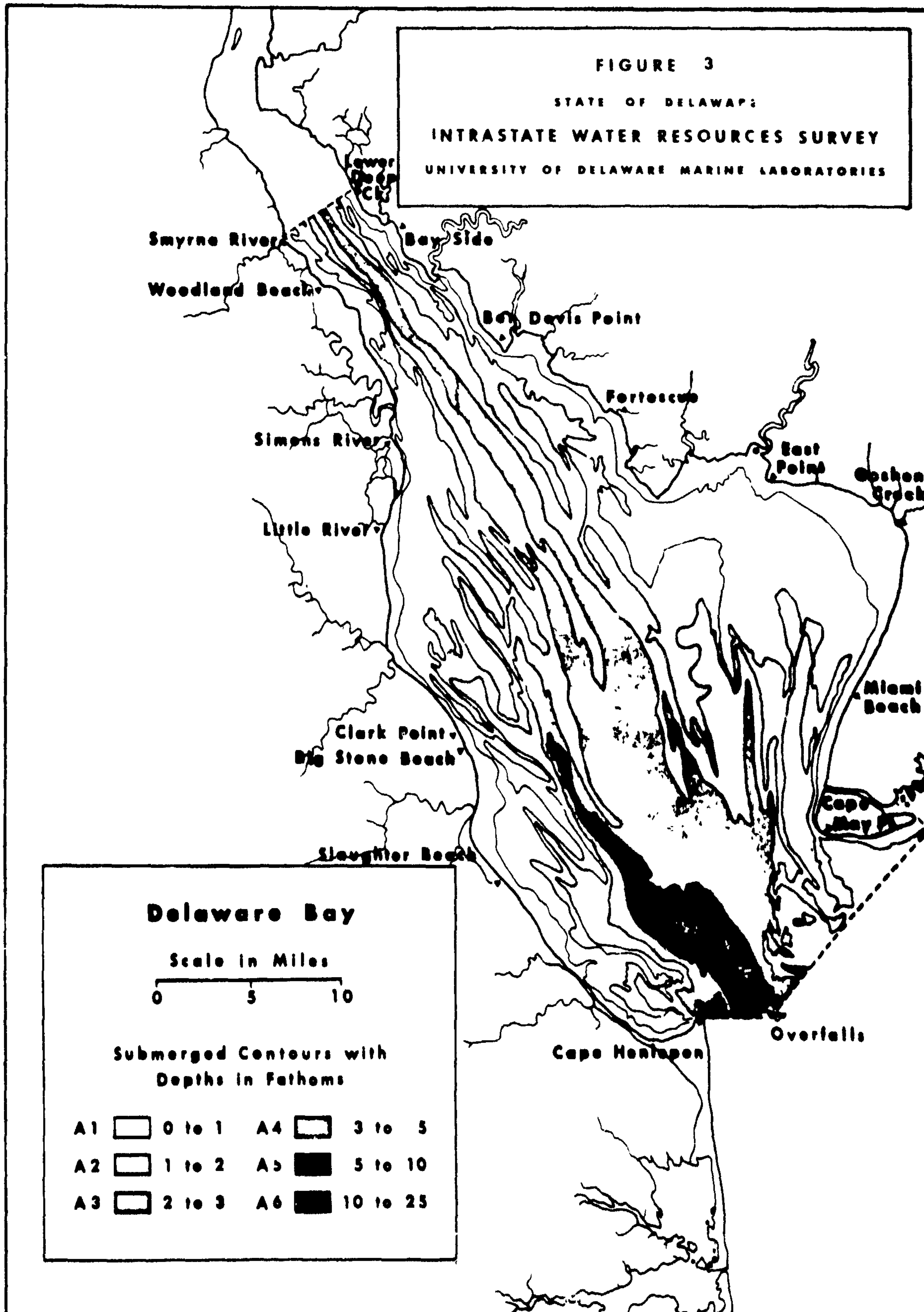
Depths	Square Miles (Statute)	Acres (x1000)	% of Delaware Portion	% of Total
A1	47	30	15.2	6.5
A2	69	44	22.3	9.6
A3	53	34	17.1	7.4
A4	42	27	13.6	5.8
A5	52	33	16.8	7.2
A6	46	29	14.9	6.4
	309	197	99.9	42.9

(C) AREA OF SUBMERGED CONTOURS IN THE NEW JERSEY OR EASTERN PORTION OF DELAWARE BAY

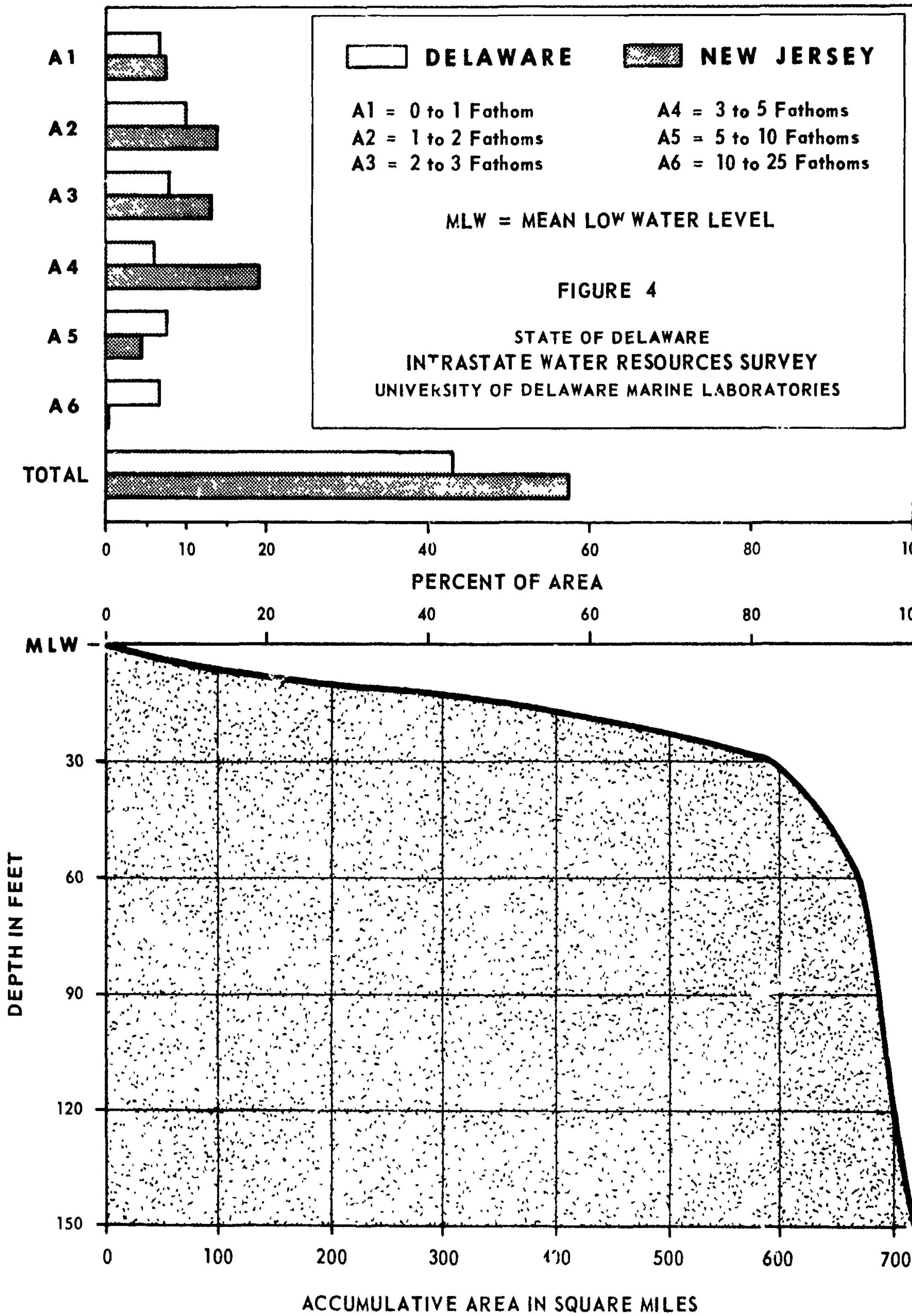
Depths	Square Miles (Statute)	Acres (x1000)	% of New Jersey Portion	% of Total
A1	51	33	12.4	7.1
A2	98	63	23.8	13.6
A3	94	60	22.9	13.1
A4	135	86	32.9	18.8
A5	31	20	7.5	4.3
A6	2	1	0.5	0.3
	411	263	100.0	57.2

b. Discussion. Although the morphometric data presented above is a beginning toward an understanding of the Delaware River estuary basin, much more work remains to be done. One fruitful research approach would be along the lines developed by geographers and agriculturalists in relating crop production with climatic and topographic conditions. The need to better define the habitats of bottom-dwelling organisms can be largely satisfied by more fully utilizing geological and morphometrical research in conjunction with studies on the physical and chemical characteristics of the water environment. The reader is invited to peruse the excellent review articles by Thorson (1957) and Hedgpeth (1957) on the interrelationships between organisms and the bay bottom and beaches.

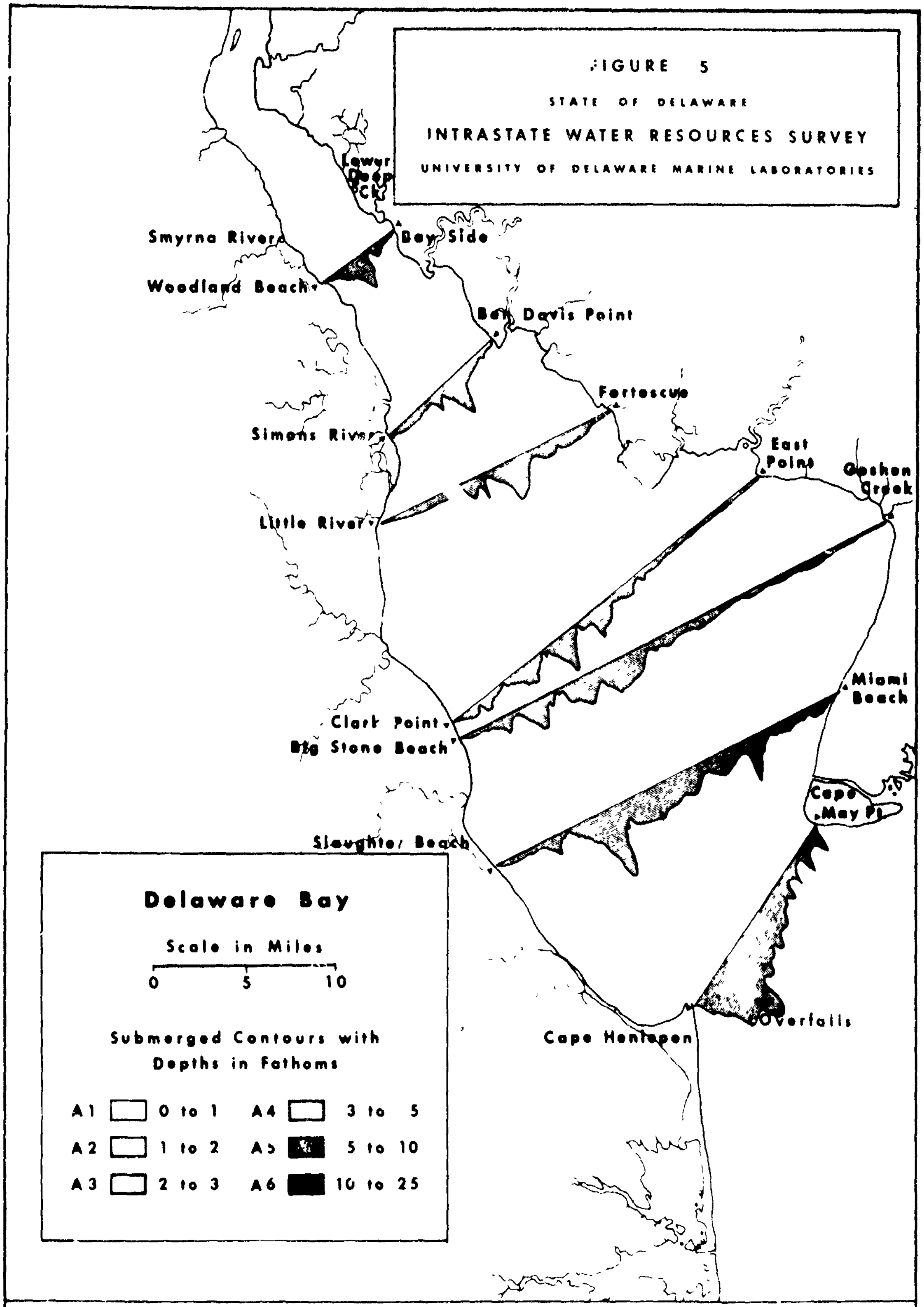
Some of the biological productivity implications suggested by the morphometric data on the Delaware Bay basin are discussed below.



SUBMERGED CONTOURS OF DELAWARE BAY. TONGUES OF DEEPER WATER RADIATE FROM THE BAY ENTRANCE INTO THE BAY. THE TERMINAL POINTS OF THE PROFILES GIVEN IN FIGURE 5 (PAGE 21-12) ARE SHOWN HERE FOR EASY COMPARISON.



THIS HYPSOGRAPHIC CURVE SHOWS THE AREA WITHIN DELAWARE BAY THAT IS ABOVE OR BELOW ANY GIVEN DEPTH (SEE TABLE 1, PAGE 21-7). FOR EXAMPLE, SLIGHTLY OVER 80% OF THE BAY IS LESS THAN 30 FEET DEEP. BAR GRAPHS SHOW THE PERCENT OF EACH DEPTH IN DELAWARE AND IN NEW JERSEY.



THIS SERIES OF PROFILES SHOWS THE VARIATIONS IN DEPTH ACROSS DELAWARE BAY AT SELECTED LOCATIONS (SEE FIGURE 3, PAGE 21-10) FROM THE HEAD OF THE BAY TO THE BAY ENTRANCE. THE SCALE OF THE LARGER DRAWING FROM WHICH THIS FIGURE WAS PRINTED IS GIVEN ON PAGE 21-8, IN (15) PROFILES.

(1) Maximum depth-surface area relation (MxD/As). By definition, a body of water having a maximum depth equal to the square root of its surface area has a depth-area relation value of 1.0. A body of water with a relationship greater than 1.0 indicates a maximum depth greater than the square root of its surface area. The larger the relation value, the greater is the overall depth of the body of water. In the case of the Delaware Bay, MxD/As is less than 1.0; it is 0.0035, a value indicating a relatively shallow body of water in regard to its area.

(2) Shore development. When comparing the length of the shoreline of a bay with the circumference of a circle having the same area as that of the bay, a ratio of 1.0 would indicate that the shoreline is entirely undeveloped, lacking any inlets, coves, or other irregular formations. The greater the development of the shoreline, the larger the value of the ratio. The ratio from US C&GS Chart #1218 for Delaware Bay is 1.26, a value indicating very little development. In brief, the shoreline shows only 1.26 times more development than that of the circumference of a circle of equal area. A shore development ratio for Chesapeake Bay is not readily available, yet it is evident that the 1,591 miles of shoreline reported for seven Maryland counties on the bay (Nicholson and Van Deusen, 1954) denote a much greater shore development than found in Delaware Bay. Much useful information would result from research upon the comparative productivity of these two bays.

(3) Morphometry and productivity. The morphometry of a body of water, as its shore development, depth, and surface area, indicates the extent of areas suitable for early development and growth of organisms of importance to food chains. Areas rich in nutrients generally provide a suitable habitat for many important organisms. The extent and geological characteristics of these areas are believed to have an influence upon overall biological productivity.

Our research experiences and the commercial fisheries statistics substantiate the general belief that the biological productivity of Delaware Bay is high. Certain of the morphometric values given in this report, as the low shore development ratio, suggest that productivity should be lower than it actually is. Generally, a shallow water area is more productive than a deep body of water, due to the greater volume of water, in relation to the total volume, that is exposed to sunlight. Since plants are dependent upon sunlight for photosynthesis (the manufacture of sugar), the depth of light penetration into deep or murky water is a limiting factor for plant growth. The shallowness of Delaware Bay, which should be ideal for phytoplankton (floating microscopic plants) production, is offset by the opaqueness of the sediment and organic detritus-laden water. Exposure to sunlight of the microscopic algae in the surface muds of intertidal areas may compensate for the general opacity of the bay water. A critical evaluation of these and other factors, in addition to the morphometry of the bay, which contribute to the high productivity, or hinder it, awaits further research data.

The tidal marshes fringing Delaware Bay were not considered in our morphometric study, due to the difficulty of obtaining meaningful data even from the large scale chart (1:80,000) used. Useful data could be obtained from an intensive study of aerial photographs. Yet it is obvious,

without performing the required tedious computation, that the banks of tidal streams greatly increase the length of the shoreline available to estuarine organisms and the substratum for the biological phenomena that occur at the mud-air interface in intertidal areas. A measure of the tidal stream shoreline, when added to the bay shoreline calculated from Chart #1218, would probably significantly increase the shore development ratio. This is only one of the important contributions that tidal marshes make to the overall biological productivity of the Delaware River estuary. Other factors in the probable role of these tidemarshes in productivity are discussed in a succeeding subsection (21.05).

The shape of the Delaware Bay basin is essentially that of a flattened funnel, with a more extensive shallow water area in its eastern side. Indeed, the only extensive intertidal flats are along the Cape May shore. The deepest areas are in the western portion of the bay. These facts are well known, but the calculations given on pages 21-8 and 21-9 present data useful in quantitative comparisons of the various portions of the bay.

Extent of the bottom contours, the geology of the bay at the various depths, and the characteristics of the water mass moving over each area play an important role in the ecology of the organisms, particularly the bottom-dwelling species, living in each area. From our observations upon these environmental factors it is evident that the relationships between the basin contour, the geology of the bay bottom, and the water masses must be understood before intelligent recommendations and decisions affecting fisheries can be made, as on: new and enlarged navigation channels; dredge spoil areas; and fisheries management areas, as spawning sanctuaries, nursery grounds, and artificial habitats.

21.04 EXTENT OF THE DELAWARE RIVER ESTUARY

The generally accepted definition of an estuary is as an arm of the ocean: a coastal tidal body of water where measurable dilution of sea water occurs. An estuary is defined, therefore, by several types of boundaries, among which the more prominent are due to variations in the transition between land and water masses caused by changes in the water level, as by tides and runoff. Further, an estuary is an integral and natural part of a watershed and the hydrologic phenomena associated with it. Estuaries are affected, therefore, by any man-caused changes in the water cycle and in the land-water relationships.

There are three geographical boundaries, as illustrated in Figure 1: lower river, Delaware Bay, and an offshore area. Along the Atlantic Coast the Fall Zone or boundary between the Piedmont and Coastal Plain generally marks the upstream limits of estuaries within watersheds (see Ward, 1958). There the low tidal amplitude is effectively blocked by the height of the Fall Zone falls and rapids (see also section 15.01, b., (2)).

Another boundary, the transition zone between the land and water masses, is critical for several reasons. From the ecological viewpoint, both the bay bottom and the air-land-water boundary are important transition zones: the geology of the bay bottom determines in part the kind of inhabiting bottom-dwelling species; the intertidal zone is an important

is an important region of photosynthetic activity and the habitat of many species which play a prominent role in estuarine productivity. The boundary between land and water surface is a function of the usual tidal fluctuation and phenomena which cause variations in that amplitude. A clearly marked horizontal boundary, the intertidal zone, exists between the low and high water level. It is a zone critical to estuarine productivity, particularly in the tidemarsh area.

Another important ecological portion of the Delaware River estuary is the segment within which the Ship John Lighthouse is located. Here extreme conditions exist for estuarine organisms, especially in the range of salinity changes. This segment of the estuary should be intensively studied, hydrographically, chemically, and biologically.

An unseen boundary, but of prime importance to ground water resource problems, is salt water intrusion into ground water supplies through fresh water-bearing strata--aquifers. This is a perennial problem in coastal areas where heavy demands upon ground water supplies or the exposure of aquifers by channel dredging bring about the danger of salt water intrusion into the coastal fresh water supplies.

The extent of the fresh water influence upon coastal waters, particularly the amount of nutrients and pollutants transported downstream into the estuary, must be considered in any estimation of estuarine and coastal biological productivity beyond the salinity influence. This is obvious, since the influence of fresh water runoff can be measured in the continental shelf water, where the salinity varies seasonally. At Five Fathom Lightship, about 28 miles due east of Cape Henlopen, the salinity of the surface water varied during the year of 1956 from 29.7 to 33.1 ‰ (salinity is recorded in parts of sea salt per thousand parts of sea water, on a weight basis, and is represented by the symbol ‰); from 30.5 to 33.2‰ at Winter Quarter Lightship (Bumpus, 1957). If 35.0‰ is taken as the salinity of undiluted sea water, then the above data represents the amount of dilution resulting mainly from the Delaware River watershed runoff. The salinity cycle at each lightship was from the higher salinity in the winter to lower salinity during the summer, with a return to the higher salinity in the fall of the year.

In the summary of a study on the offshore area of the Delaware River estuary, Ketcham (1952) traced the fresh water contribution of the Delaware River and its tributaries over a wide area (2,000 to 3,500 square miles in two surveys analyzed), outside and to the south of the entrance to Delaware Bay. The volume of fresh water influencing the salinity of this large area was computed to correspond to slightly more than two weeks flow from the Delaware River watershed.

The Southwest Drift, a southwesterly-flowing coastal current described by Miller (1952) and Ayers (1955) transports fresh water runoff from New Jersey coastal streams. Yet the major influx of fresh water, from the region of the entrance to Delaware Bay southward to the coastal region more affected by the Chesapeake Bay drainage, is from the Delaware River watershed.

It is clear from the foregoing discussion that the coastal fisheries of the Delaware Bay offshore area come under the direct influence of its watershed, and indeed, are located within the easily recognizable salinity boundaries of the Delaware River estuary.

21.05 ROLE OF TIDEMARSHES IN ESTUARINE PRODUCTION

Estuaries are spawning and nursery areas for several species of commercially valuable aquatic animals and the home of others. Evidence on the importance of estuaries to coastal fisheries is accumulating from the research of many marine laboratories, but the precise role of tidemarshes in estuarine production is less well known.

Nelson (1947) was the first to focus attention on the contributions of the land to production in the Delaware Bay. Among the several points he emphasized on physical, biological, and chemical contributions, he illustrated the interrelationships of these contributions upon the production of microscopic plants on the intertidal flats along the Cape May shore. These flats are doubly important to the shellfish industry, through the production of bacteria and algae upon which oysters and other mollusks feed, and as setting and growing areas.

Vitamin B_{12} is produced in coastal waters by microorganisms and is used by them and by higher forms of life for growth and development. Starr (1956) called attention to the role of tidemarshes as important production sites of this growth factor. He found that the waters draining from a tidal marsh in Georgia contained detritus richer in vitamin B_{12} immediately after high slack water than at any other stage of the tide or in the nearby ocean water. Starr further pointed out that the flushing process,of periodic flooding and draining of salt marshes, causes a continual exchange of nutrients between the coastal waters and the marsh lands. A similar exchange occurs between the tidemarshes and the Delaware River estuary.

The pilot study of Canary Creek Marsh near the Bayside Laboratory at Lewes indicated that all three forms of inorganic nitrogen (ammonia, nitrite, and nitrate) were, on the average, more abundant in the water immediately after the high slack period than at any other stage of the tide. The results for phosphorus (inorganic and organic) were less decisive, but the contribution of nutrients from the marsh to the tidal waters was obvious.

Canary Creek Marsh is a high-level tidal marsh, completely flooded only by the high spring tides. Upon its 123 acres grows each year a 323-ton (dry weight) plant crop, principally saltmarsh grasses. Part of this crop, through decomposition, probably forms the major portion of an estimated 84 tons (dry weight) of organic matter that is flushed from the marsh each year. The relationship between bacteria and detritus has been cited above in the vitamin B_{12} study by Starr (1956) and its importance in estuarine production has been summarized by Daiber (1959).

In a general account, Shuster (1958) utilized data from the studies on Georgia marshes and calculated that 547 pounds of sugar per acre per year are produced by microscopic plants on the tide-flooded mud surfaces of marshes. If only one-half of Delaware's 130,000 acres of tidemarshes have this level of production, this is still an annual crop of 35,555,000 pounds which is food for estuarine animals. At 10 cents a pound this

tidemarsh sugar crop produced by the microscopic plants is worth $3,555,-500. To this must be added the value of the food produced by the rooted plants, as the marsh grasses and sedges. Another role of these rooted plants is given in the Appendix, Section 21.10, a.

Dramatic evidence of the high productivity of estuaries and coastal lands is contained in a summary by Odum and Odum (1959) of what is known about the world distribution of primary production. Primary production (the rate at which energy is stored, chiefly by green plants, in the form of food) is generally recorded in grams per square meter per day (gms/M^2/-day. Corresponding values in pounds per acre per day are included below.

Three major production levels are recognized by the Odums: 1) the greatest surface area of the earth, the open ocean and desert areas, is the least productive, around 0.1 gms/M^2/day (1.2 lbs/acre/day); 2) coastal seas, shallow lakes, grasslands, and ordinary agriculture crops range upward from o.5 to 5.0 gms/M^2/day (6.1 to 60.5 lbs/acre/day, and 3) the greatest primary productivity, 5.0 to 20.0 gms/M^2/day (60.5 to 242 lbs/acre/day), occurs in some estuaries, coral reefs, some mineral springs, semi-aquatic and terrestrial plant communities on alluvial plains, evergreen forests, and intensive agriculture (as year-round sugar cane production). The Odums (1959) believe that a production rate higher than 25 gms/M^2/day (303 lbs/acre/day) cannot be maintained over a period of years, although short-period productivity may be as high as 60.0 gms/M^2/day (786 lbs/acre/-day). An essential point emphasized by the Odums is that although "man has not increased maximum primary productivity beyond that which occurs in the absence of man," he is capable of improving conditions where less than maximum production does occur.

The foregoing discussion prompts at least one question: What is the primary production rate of the Delaware River estuary? or, in other words, how near is the actual production rate to the expected maximum yield? This we do not know, but we do have data from other sources, such as fisheries statistics, which indicate high production.

It is also of interest to note that the agricultural and forest lands, and the estuaries of Delaware probably rank in the top category of primary production described by Odum and Odum (1959). There is good cause, therefore, to emphasize the fact that these natural land and water areas are top priority food and material production sites. Their value to future generations cannot be overestimated.

An overabundance of nitrogen and phosphorus due to pollution in the lower Delaware River may accidentally contribute to the productivity of the bay. To guide us in an exploration of this paradox, that is, of pollution contributing to production, as well as other factors in the overall biological production of the estuary, Kalber (1959) has outlined a working hypothesis (Appendix, 21.11, a.).

21.06 SHORE ZONE FISHES OF DELAWARE BAY

This subsection is based largely upon a one-year survey by Dr. Franklin C. Daiber of the shore zone fishes of the Delaware Bay during the period October 1952 through November 1953. Five areas were selected as sites for the survey (Daiber, 1954): Augustine Beach, Woodland Beach, Kitts Hummock, Slaughter Beach, and Lewes Beach (see Fig. 1, page 21-3). These collecting stations are approximately equidistant along the bay shore and are

characterized by steep sand beaches formed by a barrier dune with tidal marshes behind the dune. The intertidal zone at these five stations is, in general, narrow and steep, leveling off to form extensive mud or sand flats. At low tide the water over these stations is only a foot or two in depth.

a. Methods. A 25-foot beach seine with a bag was employed on 22 collecting trips made every 2 to 3 weeks to each of the five stations on the western shore of Delaware Bay. The fishes seined at each station were preserved in formalin and later were identified and measured. A record of tide and water temperature and salinity, weather condition, and other data was obtained at the time of each collection.

b. Results and conclusions. The results of the survey showed that the most abundant shore zone fishes of the Delaware Bay are euryhaline (capable of withstanding wide salinity ranges) species. This survey also indicates that the shore zone is a highly productive area for small forage (food for other animals) fishes and for the young of certain commercially important species.

The most important forage fishes of the shore zone in terms of numbers collected were:

Menidia menidia, common silversides
Anchoa mitchilli, common anchovy
Fundulus heteroclitus, common killifish
Fundulus majalis, striped killifish
Membras vagrans, rough killifish
Menidia beryllina, tidewater silversides

The most common immature or young commercial species collected were:

Brevoortia tyrannus, menhaden
Cynoscion regalis, weakfish
Pomatomus saltatrix, bluefish
Roccus saxatilus, striped bass
Paralichthys dentatus, northern flounder

Menidia menidia, the common silversides, is probably the most important forage fish of the Delaware Bay shore zone. This species was very abundant throughout the year at all of the five collection stations. It was the most abundant species at all stations, except at Augustine Beach, where it ranked second in numbers to the common anchovy, A. mitchilli. Menidia menidia is a very important food item in the diet of such commercial species as the flounder and striped bass, as well as large weakfish. The rough silversides, Membras vagrans, and the tidewater silversides, Menidia beryllina, are also quite common along the shore zone and have similar roles as forage fishes.

The common anchovy, Anchoa mitchilli, is also a very important and abundant forage fish of the Delaware Bay shore zone. This species ranked second in total numbers to the common silversides during Dr. Daiber's collection period. The anchovy is an important food item in the diet of the weakfish, Cynoscion regalis. The majority of anchovies found along the shore zone are immature; they move out to deeper water later in life (Stevenson, 1958).

The various species of killifish are quite common along the shore zone of the Delaware Bay and in the tidal creeks that flow into the Bay. The most abundant species of killifish is the common killifish, *Fundulus heteroclitus*. The striped killifish, *Fundulus majalis*, is also quite common. Killifish are important forage fishes for flounders and striped bass which move in close to shore with the tide and up into the tidal creeks.

Of the commercial species, the most abundant found along the shore zone of the Bay are the young of the menhaden, *Brevoortia tyrannus*. This species ranked high in Dr. Daiber's collections at Augustine Beach and Woodland Beach. In recent years, very large schools of yound menhaden have been very common in the shallow water near shore throughout the summer and early fall. The importance of the shore zone and tidal creeks along the Delaware Bay as nurseries for young menhaden can not be overestimated.

Dr. Daiber's records show that the young of the bluefish, *Pomatomus saltatrix*, were fairly common all along the shore zone of Delaware Bay during the summer of 1953. The beach seining records of Dr. Donald P. de Sylva and Frederick A. Kalber, Jr. for the summer of 1958, also indicate, on the basis of the large number collected, that the shore zone of the lower Delaware Bay is important as a nursery for young bluefish.

Immature striped bass, *Roccus saxatilus*, also seem to utilize the shore of Delaware Bay. Although few striped bass were taken during Dr. Daiber's survey period, collections during the summer of 1958 show that immature striped bass were quite common along the shore zone.

Young and immature individuals of several other important commercial species are also found along the shore zone of the Delaware Bay. Young weakfish, *Cynoscion regalis*, although not abundant during the 1952-1953 survey, were common within the shore zone during the summer of 1958. Young flounder, *Paralichthys dentatus*, are fairly common in the shore zone. This zone, rich in terms of small forage fishes, is a feeding area for the older flounder.

The following tables, compiled from Dr. Daiber's collection data for 1952-1953, summarize the nature of the shore zone fish population and the environmental conditions encountered by these species. The common name of each of these species is included in Table 3. A total of 13,048 individual fish, comprising 44 species classed among 20 families found in 8 orders, were collected from the five stations along Delaware Bay.

TABLE 2

WATER TEMPERATURE AND SALINITY RANGES AT THE FIVE SURVEY STATIONS AT THE TIME OF SEINING

	Temperature (°C)		Salinity (°/oo)		
	Min.	Max.	Ave.	Min.	Max.
Augustine Beach	2	28	4.6	0.8	9.9
Woodland Beach	2.5	29	8.8	3.8	14.9
Kitts Hummock	3	36	18.8	13.5	25.4
Slaughter Beach	3	32	24.3	20.8	28.2
Lewes Beach	4.5	28	27.0	23.0	29.1

TABLE 3

A SUMMARY OF THE DISTRIBUTION OF THE SHORE ZONE FISHES AT THE FIVE COLLECTING STATIONS

Stations	Number of Fishes Collected	Number of Species Collected
1. Augustine Beach	2,054	20
2. Woodland Beach	1,699	18
3. Kitts Hummock	1,089	24
4. Slaughter Beach	7,144	20
5. Lewes Beach	2,275	21

Abundance
+++ = Very common
++ = Common
+ = Few or occasional
0 = Absent

Type of Species
E = Euryhaline
F = Fresh water
M = Marine

Species	STATION 1	2	3	4	5		Common Name of Fish
Alosa sapidissima	+	+	0	0	0	E	shad
Anchoa m. mitchilli	+++	+++	+++	+++	+++	E	common anchovy
Anchoa eurystole	0	0	0	0	+	M	anchovy
Anguilla rostrata	+	0	+++	+	+	E	common eel
Apeltes quadracus	0	0	+	0	0	E	4-spined stickleback
Bairdilla chrysura	0	0	0	+	+	E	silver perch
Brevoortia tyrannus	++	+	+	++	+	E	menhaden
Carassius auratus	+	0	0	0	0	F	goldfish
Cynoscion regalis	0	0	++	+	0	M	weakfish
Cyprinodon variegatus	0	+	0	+	+	E	broad killifish
Cyprinus carpio	+	0	0	0	0	F	carp
Fundulus heteroclitus	++	++	+	+	+	E	common killifish
Fundulus majalis	+	+	+++	+	+	E	striped killifish
Fundulus ocellaris	+	+	+	+	+	E	ocellated killifish
Lucania parva	0	0	+	0	0	E	rainwater killifish

TABLE 3 Continued

Species	1	2	3	4	5		Common Name of Fish
Membras vagrans	+	+	0	+++	+	E	rough silversides
Menidia beryllina	+	+	+	+	+	E	tidewater silversides
Menidia menidia	+++	+++	+++	+++	+++	E	common silversides
Micropogon undulatus	+	+	+	+++	+	M	croaker
Roccus americana	+	0	+	0	0	E	white perch
Mugil cephalus	0	+	+	+	+	M	striped mullet
Notemigonus c. crysoleucas	+	0	0	0	0	F	golden shiner
Notropis amoenus	+	0	0	0	0	F	attractive shiner
Alosa aestivalis	+	++	+	+	+	M	glut herring
Pomoxis annularis	0	+	0	0	0	F	white crappie
Pomoxis nigromaculatus	0	+	0	0	0	F	black crappie
Otophidium marginatum	0	0	+	0	0	M	cusk eel
Roccus saxatilus	0	0	+	0	0	E	striped bass
Sphoeroides maculatus	0	0	0	+	+	M	northern swellfish
Syngnathus fuscus	0	+	+	+	0	E	pipefish
Notropis bifrenatus	+	0	0	0	0	F	bridled minnow
Hyporamphus unifasciatus	0	0	0	0	+	M	halfbeak
Orthopristis chrysopterus	0	0	0	+	0	M	pigfish
Sciaenops ocellatus	0	0	0	0	+	M	red drum
Alosa pseudoharengus	0	0	+	0	0	M	alewife
Pomatomus saltatrix	+	+	0	0	+	M	bluefish
Strongylura marina	0	+	0	+	+	M	needlefish
Trachinotus carolinus	0	0	0	0	+	M	common pompano
Pogonias cromis	0	0	++	0	0	M	black drum
Mugil curema	0	0	+	+	0	E	white mullet

TABLE 3 Concluded

Species	1	2	3	4	5		Common Name of Fish
Trinectes maculatus fasciatus	0	0	+	0	0	M	hog choker
Notropis rubellus	+	0	0	0	0	F	rosy-faced shiner
Gasterosteus aculeatus	0	+	0	0	0	E	3-spined stickleback
Menticirrhus saxatilis	0	0	+	0	+	M	kingfish

(Columns 1–5: STATION)

TABLE 4

ANALYSIS OF THE SHORE ZONE FISH POPULATION BY SPECIES

I. Order Ostariophysi

Family Cyprinidae

Cyprinus carpio (Linnaeus)
Carassius auratus (Linnaeus)
Notemigonus c. chrysoleucas (Mitchill)
Notropis amoenus (Abbott)
Notropis bifrenatus (Cope)
Notropis rubellus (Agassiz)

II. Order Apodes

Family Anguillidae

Anguilla rostrata (Lesueur)

III. Order Isospondyli

Family Clupeidae

Alosa sapidissima (Wilson)
Alosa aestivalis (Mitchill)
Alosa pseudoharensus (Wilson)
Brevoortia tyrannus (Latrobe)

Family Engraulidae

Anchoa mitchilli (Cuvier)
Anchoa eurystole (Swain & Meek)

IV. Order Haplomi

Family Cyprinodontidae

TABLE 4 Continued

Fundulus heteroclitus (Linnaeus)
Fundulus majalis (Walbaum)
Fundulus ocellaris (Jordan and Gilbert)
Cyprinodon variegatus (Lacepede)
Lucania parva (Baird and Girard)

V. Order Synentognathi

Family Belonidae

Strongylura marina (Walbaum)

Family Hemirhamphidae

Hyporhamphus unifasciatus (Ranzani)

VI. Order Thoracostei

Family Gasterosteidae

Apeltes quadracus (Mitchill)

Gasterosteus aculeatus (Linnaeus)

VII. Order Lophobranchii

Family Syngrathidae

Syngnathus fuscus (Storer)

VIII. Order Acanthopterygii

Family Atherinidae

Menidia menidia notata (Mitchill)

Menidia beryllina (Cope)

Membras vagrans (Goode and Bean)

Family Mugilidae

Mugil cephalus (Linnaeus)

Mugil curema (Cuvier)

Family Carangidae

Trachinotus carolinus (Linnaeus)

Family Centrarchidae

Pomoxis nigromaculatus (Rafinesque)
Pomoxis annularis (Lesueur)

TABLE 4 Continued

Family Pomatomidae

Pomatomus saltatrix (Linnaeus)

Family Serranidae

Roccus saxatilis (Walbaum)
Roccus americana (Gmelin)

Family Haemulidae

Orthopristis chrysopterus (Linnaeus)

Family Sciaenidae

Cynoscion regalis (Bloch and Schneider)
Bairdiella chrysura (Lacepede)
Sciaenops ocellatus (Linnaeus)
Micropogon undulatus (Linnaeus)
Menticirrhus saxatilus (Block and Schneider)
Pogonias cromis (Linnaeus)

Family Tetraodontidae

Spheroides maculatus (Bloch and Schneider)

Family Ophidiidae

Otophidium marginatum (De Kay)

Family Soleidae

Trinectes maculatus fasciatus (Lacepede)

TABLE 5

MAXIMUM AND MINIMUM WATER TEMPERATURES AND SALINITIES ENCOUNTERED BY THE MORE ABUNDANT SPECIES OF FISHES

	TEMPERATURE			SALINITY		
SPECIES	1953	°C.	Station	1953	°/oo	Station
Menidia	23 Jun	36.0	Kitts	14 Sep	29.1	Lewes
menidia	27 Jan	3.0	Kitts	20 May.	0.8	Augustine
Anchoa	23 Jun	36.0	Kitts	14 Sep	29.1	Lewes
mitchilli	17 Feb	5.0	Lewes	20 May	0.8	Augustine
Fundulus	23 Jun	36.0	Kitts	14 Sep	29.1	Lewes
majalis	27 Jan	3.5	Slaughter	9 Jul	4.7	Augustine
Brevoortia	23 Jun	36.0	Kitts	9 Jul	25.5	Slaughter
tyrannus	29 Apr	12.5	Woodland	20 May	0.8	Augustine
Alosa	20 May	23.5	Kitts	29 Apr	26.7	Lewes
aestivalis	3 Apr	12.0	Woodland	3 May	4.6	Kitts

TABLE 6

MAXIMUM AND MINIMUM WATER TEMPERATURES AND SALINITIES ENCOUNTERED BY SOME OF THE LESS ABUNDANT SPECIES

SPECIES	1953	°C.	Station	1953	°/oo	Station
Anguilla	3 Aug	25.5	Slaughter	11 Mar	26.5	Lewes
rostrata	17 Feb	2.0	Augustine	17 Feb	2.0	Augustine
Cynoscion	1 Sep	27.8	Slaughter	14 Sep	29.1	Lewes
regalis	1 Oct	19.4	Lewes	23 May	18.0	Kitts
Fundulus	23 Jun	32.0	Slaughter	23 Jun	24.4	Slaughter
heteroclitus	19 Dec*	3.5	Augustine	20 Apr	0.8	Augustine
Membras	1 Sep	29.1	Slaughter	14 Sep	29.1	Lewes
vagrans	1 Oct*	19.6	Slaughter	1 Sep	8.9	Augustine
Menidia	1 Sep	28.0	Lewes	19 Dec*	29.0	Lewes
beryllina	17 Feb*	2.0	Augustine	20 Apr	0.8	Augustine
Micropogon	4 Jun	25.0	Kitts	27 Jan	28.5	Lewes
undulatus	27 Jan	3.5	Slaughter	4 May	1.2	Augustine

*1952

TABLE 7

FISHES FOUND IN THE SHORE ZONE OF DELAWARE BAY

LISTED ACCORDING TO

THE NATURE OF THEIR RESIDENCE

I. Resident at all stages

Menidia Menidia
Menidia beryllina
Membras vagrans
Fundulus heteroclitus
Fundulus majalis

II. Resident only during immature stages.

Anchoa m. mitchilli

III. Immature offspring of breeding migrants.

Brevoortia tyrannus
Cynoscion regalis
Micropogon undulatus
Pogonias cromis
Bairdiella chrysura

IV. Immature migrants.

Pomolobus aestivalis
Roccus saxatilus
Trachinotus carolinus
Pomatomus saltatrix

V. Accidentals

Apeltes quadracus
Carassius auratus
Cyprinus carpio
Gasterosteus aculeatus
Lucania parva
Menticirrhus saxatilis
Notemigonus crysoleucas
Notropis amoenus
Notropis rubellus
Notropis bifrenatus
Pomoxis annularis
Pomoxis nigromaculatus
Otophidium marginatum
Fundulus ocellaris
Alosa pseudoharengus
Spheroides maculatus
Orthopristis chrysopterus
Sciaenops ocellatus
Hyporhamphus unifasciatus
Trinectes maculatus fasciatus
Alosa sapidissima
Anchoa eurystole
Mugil curema
Roccus americana
Mugil cephalus
Cyprinodon variegatus
Strongylura marina

TABLE 8

THE SIX MOST ABUNDANT FISH SPECIES AT EACH OF THE SURVEY STATIONS, RANKED ACCORDING TO THEIR ABUNDANCE

Augustine Beach

1. Anchoa mitchilli
2. Menidia Menidia
3. Brevoortia tyrannus
4. Menidia beryllina
5. Notemigonus crysoleucas
6. Fundulus heteroclitus

Woodland Beach

1. Menidia menidia
2. Anchoa mitchilli
3. Menidia beryllina
4. Brevoortia tyrannus
5. Alosa aestivalis
6. Fundulus heteroclitus

Kitts Hummock

1. Menidia menidia
2. Fundulus majalis
3. Anchoa mitchilli
4. Anguilla rostrata
5. Cynoscion regalis
6. Pogonias cromis

Slaughter Beach

1. Menidia menidia
2. Anchoa mitchilli
3. Micropogan undulatus
4. Membras vagrans
5. Brevoortia tyrannus
6. Bairdiella chrysura

Lewes Beach

1. Menidia menidia
2. Anchoa mitchilli
3. Alosa aestivalis
4. Menidia beryllina
5. Trachinotus carolinus
6. Anchoa eurystole

21.07 COMMENTS ON THE ECOLOGY OF ESTUARINE INVERTEBRATES

Estuarine ecology, or interrelationships among estuarine organisms and their environment, is too large a topic to be adequately discussed here. There are, however, certain aspects of estuarine ecology pertinent to biological production that will be outlined and examples given. Our attention will be mainly upon a few selected species, on estuarine invertebrates as food for other animals, and how the environment, particularly salinity, forms a barrier to the distribution of estuarine organisms.

a. Invertebrates as food. Invertebrate animals play an important role in the overall productivity of the Delaware River estuary. A portion of this total production, as of oysters, clams, squid, and blue crabs, is harvested directly as food for man. Many other species of invertebrates, chiefly marine worms, mollusks, and crustacea, are food for fishes, some of which are commercially harvested. Although it has not been emphasized previously in this account that the total productivity of our coastal waters is an important part of our economy, those invertebrates we use as

food and those species eaten by the fishes we harvest have an obvious direct or indirect economic value.

The second group of invertebrates, those that are food for fishes. are not so conspicuous as those harvested for human food, but their value can not be overlooked. Accumulating research evidence indicates that the disappearance of these food organisms could markedly affect our coastal fisheries.

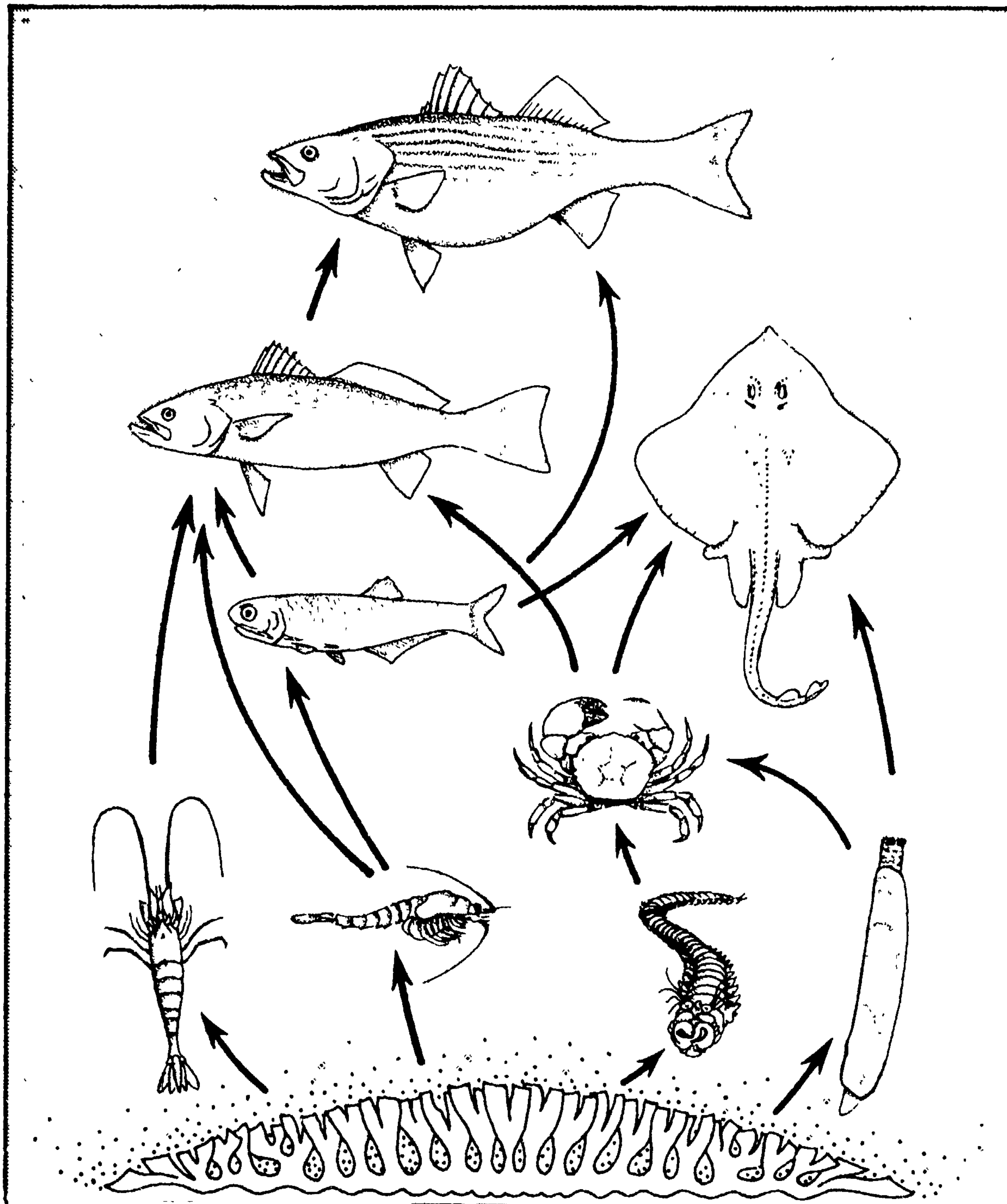
When a group of organisms are interdependent due to their diets, these interrelationships are shown by a food web diagram. One use of a food web diagram is to illustrate the direction of food energy transfer from a plant source through a series of herbivores and carnivores. One such web is described below and is illustrated with a few selected species in Figure 6, on page 21-29. Many other species, that also are involved, are not mentioned because the simplified version of a food web serves best to highlight major food pathways.

(1) An estuarine food web. Several years ago Dr. Franklin C. Daiber, Mr. William H. Amos, and the writer showed the animals concerned and explained to a television audience the significance of the food web in which the weakfish occurred (WDEL-TV, University of Delaware "Search" program, May 1, 1955: "There is More in the Water than Fish"). Since then certain organisms within this web have been studied in the Delaware River estuary. A diet study of the striped bass in Chesapeake Bay had been reported previously by Hollis (1952). The data summarized in Tables 9 thru 12 clearly indicate the extent of the diet of the predators, but more research is required to determine the nutritional value of the food species.

Hollis (1952) found seasonal as well as regional variations in the food eaten by striped bass since these fish range throughout waters of all salinities, from ocean water to fresh water, and are found in Chesapeake Bay throughout the year. The observations summarized in Table 9, on page 21-30, do not reveal these variations which the reader will find upon consulting Hollis (1952). The striped bass feeds more abundantly during the colder period of the year as shown by the percentage of fishes which had food in their stomachs during the summer (49 percent), autumn (52 percent), winter (70 percent), and spring (80 percent). Hollis (1952) found that 95 percent of the weight of all food items were fish; crustaceans were of secondary importance, furnishing less than 2 percent of the diet by weight.

A preliminary observation on the diet of weakfish by Dr. Daiber is given in Table 10. The data show that crustaceans occur most frequently in the diet of the weakfish, while mollusks and fishes also supply a sizeable portion of the diet.

The frequency of occurrence method of summarizing the data reported in Tables 9 thru 11 is used by fishery biologists to obtain an index to the relative importance of the food organisms. Data so reported give the number of stomachs in which the same food occurred. Since some stomachs contained more than one food organism, the total number of occurrences was higher than the number of food-filled stomachs studied.



A SIMPLIFIED FOOD WEB ILLUSTRATING SOME OF THE PATHWAYS OF FOOD IN THE FOOD PYRAMID INVOLVING THE WEAKFISH. THE ARROWS POINT TO THE CONSUMERS. THE INSERT (RIGHT) IDENTIFIES EACH ORGANISM. (MODIFIED FROM DAIBER, 1959)

STRIPED BASS

WEAKFISH SKATE

ANCHOVY

MUD CRAB

GLASS SHRIMP, MYSID SHRIMP, CLAM WORM, RAZOR CLAM

ORGANIC DETRITUS AND PLANT LIFE

FIGURE 6

STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
UNIVERSITY OF DELAWARE MARINE LABORATORIES

TABLE 9

FREQUENCY OF OCCURRENCE OF FOOD ORGANISMS
IN THE STOMACHS OF
STRIPED BASS, *Roccus saxatilis*

(Summarized from examination of 968 stomachs from striped bass collected during a 1-year period in Chesapeake Bay: Hollis, 1952)

FOOD ORGANISMS	FREQUENCY OF OCCURRENCE Number of Stomachs	Percent of Stomachs
ALGAE	5	0.6
WORMS	12	1.3
MOLLUSKS	4	0.5
CRUSTACEANS		
Cladocerans	61	6.4
Shrimps	47	4.9
Isopods	45	4.7
Blue crab	17	1.8
Mysids	16	1.7
Other species	16	1.7
FISHES	818	84.6
Anchovy, common	218	22.6
Spot	135	14.0
Croaker	124	12.9
Menhaden	108	11.2
Herring sp.	75	7.8
Weakfish	17	1.8
Other species	111	11.5
Unidentified species	185	19.2
BAIT	97	10.1
UNIDENTIFIED SPECIES	9	0.9

TABLE 10

FREQUENCY OF OCCURRENCE OF FOOD ORGANISMS
IN THE STOMACHS OF
WEAKFISH, *Cynoscion regalis*

(Dr. Franklin C. Daiber: unpublished observations upon 205 stomachs of weakfish, size range 12-30 cm, with a mean standard length of 19 cm, during July-October 1952, from Delaware Bay)

FOOD ORGANISMS	FREQUENCY OF OCCURRENCE			
	Number of Stomachs		Percent of Stomachs	
WORMS				
Nemertineans		1		0.5
Gephyreans		1		0.5
Nereids		1		0.5
MOLLUSKS	71		34.6	
Solen viridis		65		31.7
Loligo sp.		4		2.0
Mytilus edulis		2		0.9
CRUSTACEANS	193		94.1	
Neomysis sp.		130		63.4
Crago sp.		33		16.1
Ampelisca sp.		11		5.4
Erichthonius brasiliensis		10		4.9
Other Corophiids		1		0.5
Labidocera sp.		8		3.9
Decapod remains		5		2.4
Ovalipes ocellatus		1		0.5
Gammarids		1		0.5
Isopods		1		0.5
Limulus polyphemus		1		0.5
FISHES	74		37.1	
Anchoa sp.		71		3.4
Poronotus tricanthus		2		0.9
Menidia sp.		1		0.5
Unidentified fish remains		66		32.2

TABLE 11

FREQUENCY OF OCCURRENCE OF FOOD ORGANISMS
IN THE STOMACHS OF
CLEARNOSE SKATES, *Raja eglanteria*

(Data obtained from observations on 363 skate stomachs containing food: Fitz, 1956)

FOOD ORGANISMS	FREQUENCY OF OCCURRENCE	
	Number of Stomachs	Percent of Stomachs
WORMS		
Nereis limbata	9	2.4
MOLLUSKS		
Ensis directus	131	36.0
Solen viridis	41	11.2
Loligo pealii	8	2.2
Crepidula fornicata	2	0.6
Modiolus demissus	1	0.3
CRUSTACEANS		
Crago septemspinosus	218	60.0
Neopanope texana	74	20.0
Pagurus pollicaris	50	13.7
Pagurus longicarpus	50	13.7
Libinia dubia	48	13.2
Ovalipes ocellatus	36	9.9
Neomysis americana	28	7.7
Panopeus herbstii	26	7.1
Eurypanopeus depressus	24	6.6
Ampelisca macrocephala	18	4.9
Chloridella empusa	9	2.4
Euceramus praelongus	9	2.4
FISHES		
Cynoscion regalis	26	7.1
Lophsetta aquosa	15	4.1
Anchoa mitchilli	4	1.1
Peprilus alepidotus	3	0.8
Bairdiella chrysura	2	0.6
Rissola marginata	2	0.6
Merluccius bilinearis	2	0.6
Syngnathus fuscus	1	0.3
Micropogon undulatus	1	0.3
Raja eglanteria	1	0.3
Unidentified fish remains	49	13.4

TABLE 12

FOOD ORGANISMS FOUND IN THE STOMACHS OF THE COMMON ANCHOVY, *Anchoa mitchilli*

(Data obtained from observations on 476 anchovy stomachs containing food; anchovies measured 15-84 mm in standard length: Stevenson, 1958)

FOOD ORGANISMS	TOTAL NUMBER OF FOOD ORGANISMS: Number	TOTAL NUMBER OF FOOD ORGANISMS: Percent	RELATIVE ABUNDANCE: Rank
DIATOMS	391	3.3	8
CHAETOGNATHS	7	0.1	12
MOLLUSKS			
Snails	618	5.2	5
Bivalves	24	0.2	7
CRUSTACEANS			
Copepods	6,376	53.6	1
Crab zooea and megalops	2,724	22.9	3
Mysids	581	4.9	2
Amphipods	88	0.7	4
Ostracods	16	0.1	9
Shrimps	14	0.1	10
FISHES			
Fishes	19	0.2	6
Fish eggs	1,042	8.8	11

Comparable data are not available for the common anchovy (Table 12), where the total number and rank of the food organisms found in 476 stomachs is reported. This method, giving a rank of relative abundance based upon a calcualtion of the abundance of each food item, serves to show the species which were consistently present in the stomachs of the anchovies.

A comparison of the diets of striped bass, weakfish, clearnose skate, and the common anchovy reveal that certain food organisms are eaten by all four, as the mysid shrimps, but that the major food organisms are different for each fish (see also Table 13). The anchovy feeds upon smaller animals than do the adults of the other three species. Skates feed heavily upon organisms that burrow in or feed upon the bay bottom. The weakfish also feeds upon these bottom-dwelling species as well as swimming ones, while the striped bass is chiefly a predator of fishes. More important, however, are the chains of food energy transfer that cut across and connect the diets of the four fishes. When several of these food chains, like the one including phytoplankton-mysids-anchovies-weakfish-skate, are placed together a food web diagram results (Figure 6).

These interrelationships between the various species as represented by their diets and by their predators, although probably in balance over a long period of time, show seasonal and yearly fluctuations. If only one species is considered, like the weakfish, then any environmental change that drastically reduces or favors the populations of its food or its predators can have a marked effect upon the weakfish population. Generally, fisheries biologists believe that fluctuations in the abundance of one species are offset by an abundance of other species, so that over a period of time the gross productivity of the estuary remains relatively stable.

An economic headache can arise from this probable pattern of overall estuarine production stability. Suppose, to illustrate with an over-simplified case, that the decline of a commercial food fish such as the weakfish was balanced by an increase of a trash fish, the skate. Although the total tons of fish flesh produced per year might be the same as for the reverse situation of abundant weakfish, few skates, and the overall estuarine productivity unchanged, there would be fewer fishes for food. This is an important point for an economist to keep in mind when evaluating the production of a species in contrast to overall estuarine production.

TABLE 13

ESTIMATE OF THE RELATIVE OCCURRENCE OF SELECTED FOOD ORGANISMS IN THE DIETS OF FOUR SPECIES OF FISHES (Tables 9 through 12)

Symbols indicate the approximate abundance of food items:

- \- = absent or negligible
- \+ = present
- ++ = common
- +++ = abundant
- ++++ = major food item

SELECTED FOOD ORGANISMS	STRIPED BASS	WEAKFISH	CLEARNOSE SKATE	COMMON ANCHOVY
ALGAE	-	-	-	+
WORMS	+	+	+	-
MOLLUSKS	-	++	+++	+
CRUSTACEANS	+	++++	++++	++++
Mysids	+	++++	+	+++
Shrimps	+	++	++++	+
Copepods	-	-	-	++++
Mud crabs	-	-	+++	-
FISHES	++++	++	++	+
Anchovy	++++	+++	+	-
Weakfish	+	-	++	-

(2) Zooplankton productivity. In the foregoing section, especially in Tables 10 and 12, several small animals were reported as abundant in the diets of weakfish and anchovies. These and other small current-drifted animals, the zooplankton, form a large source of food for larger animals. Since changes in their abundance can have a direct effect upon animal populations dependent upon them for food, the quantity and quality of the zooplankton is one index to the productivity of the estuary. Cronin (1954b), reporting upon a 2-year study of the zooplankton, calculated that, if the entire Delaware River estuary had an average zooplankton content of one-half gallon in each one million gallons of water, there would be over 12 million pounds of these small food organisms present.

The bulk of this small animal-food crop is comprised of five crustaceans: *Acartia tonsa*, *Eurytemora hirundoides* and *affinis*, *Gammarus fasciatus*, and *Neomysis americana*. Each of these and the many other species involved shows its own relationship to salinity, temperature, and other environmental factors. According to Cronin (1954b), *Acartia tonsa* and the two species of Eurytemora are found in greatest numbers in the lower river-upper bay portion of the estuary where the salinity range is generally

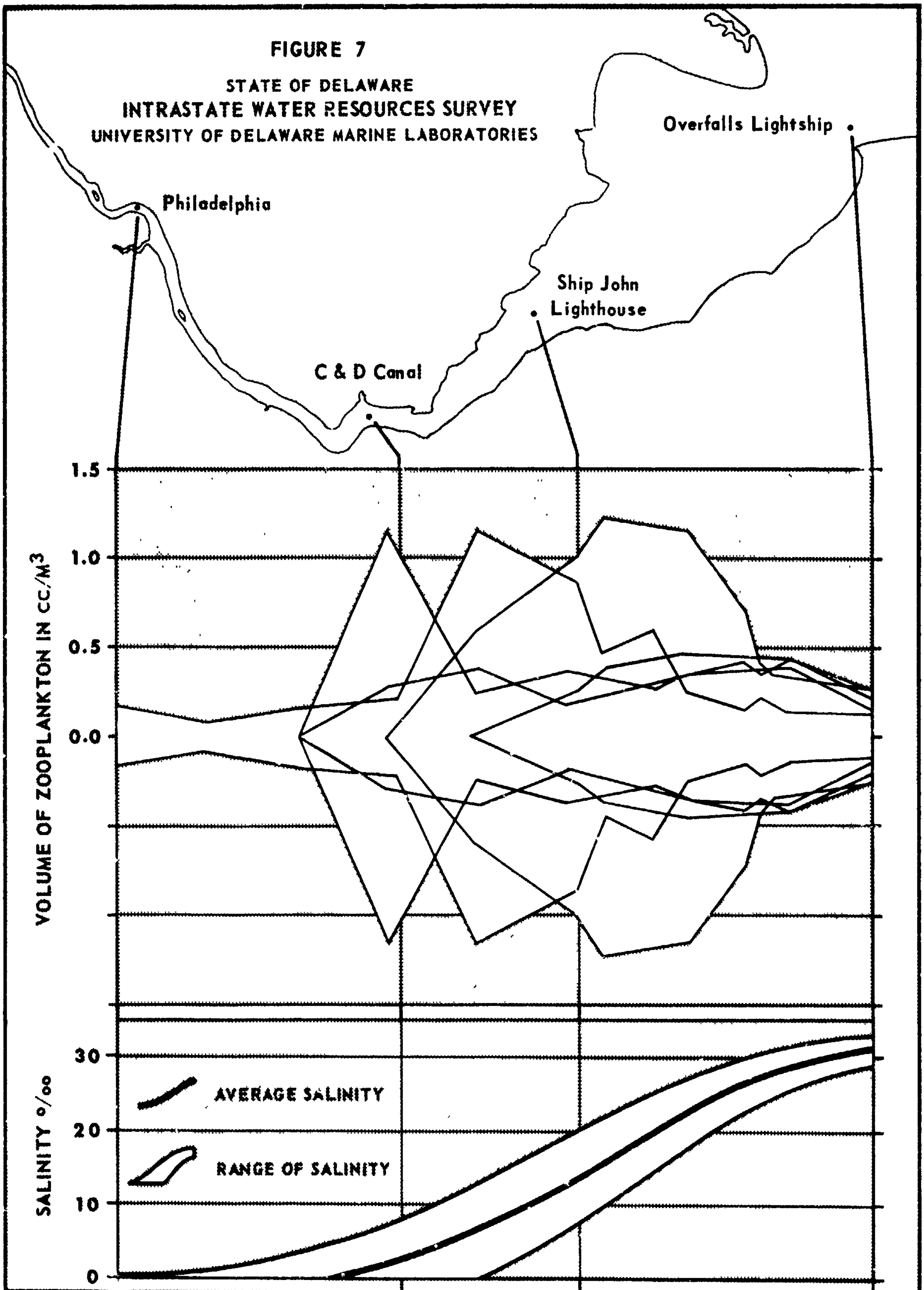
from 5 to 25 °/oo. Gammarus fasciatus is found in greatest numbers upstream from these three, in waters less than 5 °/oo. Another species, Cyclops viridis, is most abundant in fresh water but is found in decreasing abundance down to but not below Ship John Lighthouse. At Ship John two species of Centropages, typicus and hamatus, first appear in downbay samples, being most numerous in the region of Overfalls Lightship..

Evidence of the extent of zooplankton productivity in the Delaware River estuary is given by the studies of Cronin (1954b), Hulburt (1957), and Hopkins (1958a). A summary of the total volume of zooplankton collected on five cruises from the Overfalls Lightship to Philadelphia (Cronin, 1954b) is given in Figure 7. This figure graphically shows that the portion of the estuary, where the extremes in salinity ranged from nearly fresh water to over 30 °/oo, and averaged 2-30 °/oo, in which the largest zooplankton crop was repeatedly harvested by Cronin (1954b). Hulburt (1957) believed that the large numbers of Neomysis within the bay, and presumably other marine zooplankton species, was due largely to two factors: the accumulation of animals which came from the coastal waters outside the bay, and, during spring and summer, addition to this stock by reproduction.

The zooplankton richness of the nearshore and coastal waters was revealed by the studies of Hopkins. Exploratory nighttime offshore surface plankton tows made during the summer of 1958, showed that the quantity of zooplankton, particularly the mysids, fell off sharply beyond one-half mile of the shoreline. Further evidence of the relative abundance of zooplankton species in the alongshore waters was reported by Hopkins (1958a) and is summarized here in Table 14, on page 21-38. Comparable information on comb jellies and copepods was not reported by Hopkins because of the difficulty and extra time required to deal with these animals and yet accomplish the primary task of separating the mysids from the plankton samples. During the first portion of his study Hopkins recorded that the mysids were never more than 15 percent, with an average of 5 percent, of the combined volume of copepods and detritus in 17 plankton tows from November 1956 to April 1957. This finding corroborates the observations of Cronin (1954b).

Data on the range in numbers and volume of the various zooplankton animals, as recorded in Tables 14 and 15, furnish information on the variability of these animals in the plankton. The narrower the range between the minimum and maximum values, the more consistent the contribution of the population to overall productivity. Some of these ranges are recorded in Table 16A along with a seasonal index. This index reveals the percentage of the year average, taken as 100 percent, at which each plankton group stands during each season. These range and index values serve to highlight the evenness or the sporadic nature of the rise and fall of each plankton group during the year. The high index for decapod larvae during the summer, resulting from spawning in the spring, serves to further indicate that the success of crab populations, such as the blue crab for example, may be largely dependent upon the environmental and predator conditions during the summer months when the greatest number of larvae exposed to these conditions.

A comparison of the zooplankton groups listed in Table 14 with the food organisms listed in Tables 10 and 12, shows the relative importance



VOLUME OF ZOOPLANKTON PRESENT IN THE CHANNEL OF THE DELAWARE RIVER ESTUARY DURING FIVE CRUISES. COMPARE THESE VOLUMES WITH THE AVERAGE SALINITY CURVE AND RANGE OF SALINITY. (ADAPTED FROM CRONIN, 1954a, 1954b)

TABLE 14

NUMERICAL COMPOSITION, IN PERCENT, OF LARGER ZOOPLANKTON
COLLECTED BIWEEKLY ON 24 FLOODING TIDES
APRIL 1957 THROUGH APRIL 1958
(Based upon data obtained by Hopkins, 1958a)

T = Trace (less than 1%).
* = Worms; includes Platyhelminthes, Nemertea, and Annelida.
** = Miscellaneous; includes Cephalopods, Pteropods, Salps, and *Limulus* larvae.
*** = Stomatopod larvae are included.

ZOOPLANKTON	SPRING			SUMMER			AUTUMN			WINTER			ONE-YEAR AVERAGE
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	
Mysids	60	79	90	9	49	78	30	56	85	75	92	99	69
Amphipods	T	3	7	T	T	1	T	6	13	T	2	11	3
Isopods	T	2	8	T	T	T	T	2	10	T	T	T	1
Shrimps	0	1	5	T	T	T	T	2	6	T	T	1	1
Cumaceans	T	5	8	T	1	4	T	7	32	T	3	9	4
Crabs	0	T	T	0	T	T	0	T	1	0	0	0	T
Chaetognaths	0	5	18	0	T	1	4	21	44	T	1	4	7
Worms *	T	T	1	T	T	T	T	T	1	T	T	T	T
Coelenterates	T	1	6	0	T	1	T	2	4	0	2	11	1
Miscellaneous **	0	0	0	T	T	T	0	T	T	0	0	0	T
Decapod larvae ***	0	5	22	21	50	89	0	3	13	0	0	0	15

TABLE 15

VOLUMETRIC COMPOSITION, IN PERCENT, OF LARGER ZOOPLANKTON
COLLECTED BIWEEKLY ON 24 FLOODING TIDES
APRIL 1957 THROUGH APRIL 1958
(Based upon data obtained by Hopkins, 1958a)

T = Trace (less than 1%).
* = Worms; includes Platyhelminthes, Nemertea, and Annelida.
** = Miscellaneous; includes Cephalopods, Pteropods, Salps, and *Limulus* larvae.
*** = Stomatopod larvae are included.

ZOOPLANKTON	SPRING			SUMMER			AUTUMN			WINTER			ONE-YEAR AVERAGE
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	
Mysids	40	69	90	11	55	86	12	58	89	66	84	98	66
Amphipods	1	6	16	T	1	3	T	8	14	T	5	16	5
Isopods	T	4	17	T	1	4	T	5	23	T	1	4	3
Shrimps	0	5	14	T	2	4	T	13	36	T	9	22	7
Cumaceans	T	4	6	T	1	5	T	2	7	T	1	2	2
Crabs	0	T	T	0	1	3	0	T	T	0	0	0	T
Chaetognaths	0	5	14	0	T	T	1	10	20	T	1	4	4
Worms *	T	4	16	T	1	2	T	2	12	T	T	T	2
Miscellaneous **	0	0	0	T	1	6	0	T	T	0	0	0	T
Decapod larvae ***	1	4	17	10	38	83	0	3	6	0	0	0	11

TABLE 16A

THE RANGE BETWEEN THE MINIMUM AND MAXIMUM AND THE SEASONAL INDEX, IN PERCENT, OF THE NUMBERS AND VOLUMES OF CERTAIN ZOOPLANKTON GROUPS SELECTED FROM TABLES 14 AND 15

(Based upon the data obtained by Hopkins, 1958a)

DATA ON NUMBERS:

ZOOPLANKTON	SPRING Range	SPRING Index	SUMMER Range	SUMMER Index	AUTUMN Range	AUTUMN Index	WINTER Range	WINTER Index
Mysids	30	114	69	71	55	81	24	133
Amphipods	7	100	1	13	13	200	11	67
Decapod larvae	22	33	68	330	13	20	0	0

DATA ON VOLUMES:

ZOOPLANKTON	SPRING Range	SPRING Index	SUMMER Range	SUMMER Index	AUTUMN Range	AUTUMN Index	WINTER Range	WINTER Index
Mysids	50	105	75	83	77	88	32	127
Amphipods	15	120	3	20	14	160	16	100
Decapod larvae	16	36	73	345	6	27	0	0

of these zooplankton species to weakfish and anchovies. Roughly estimated, two-thirds of the weight of the weakfish harvested yearly by sport and commercial fishermen is due, directly or indirectly, to the zooplankton and plankton-feeding animals upon which weakfish feed. One species, Neomysis americana, is an important portion of that diet. Hopkins (1958b) concluded that the abundance of mysids and the frequency of their occurrence in fish stomachs indicates that mysids are an important link in the food chain of the estuarine and inshore coastal waters of the northeastern coast of America.

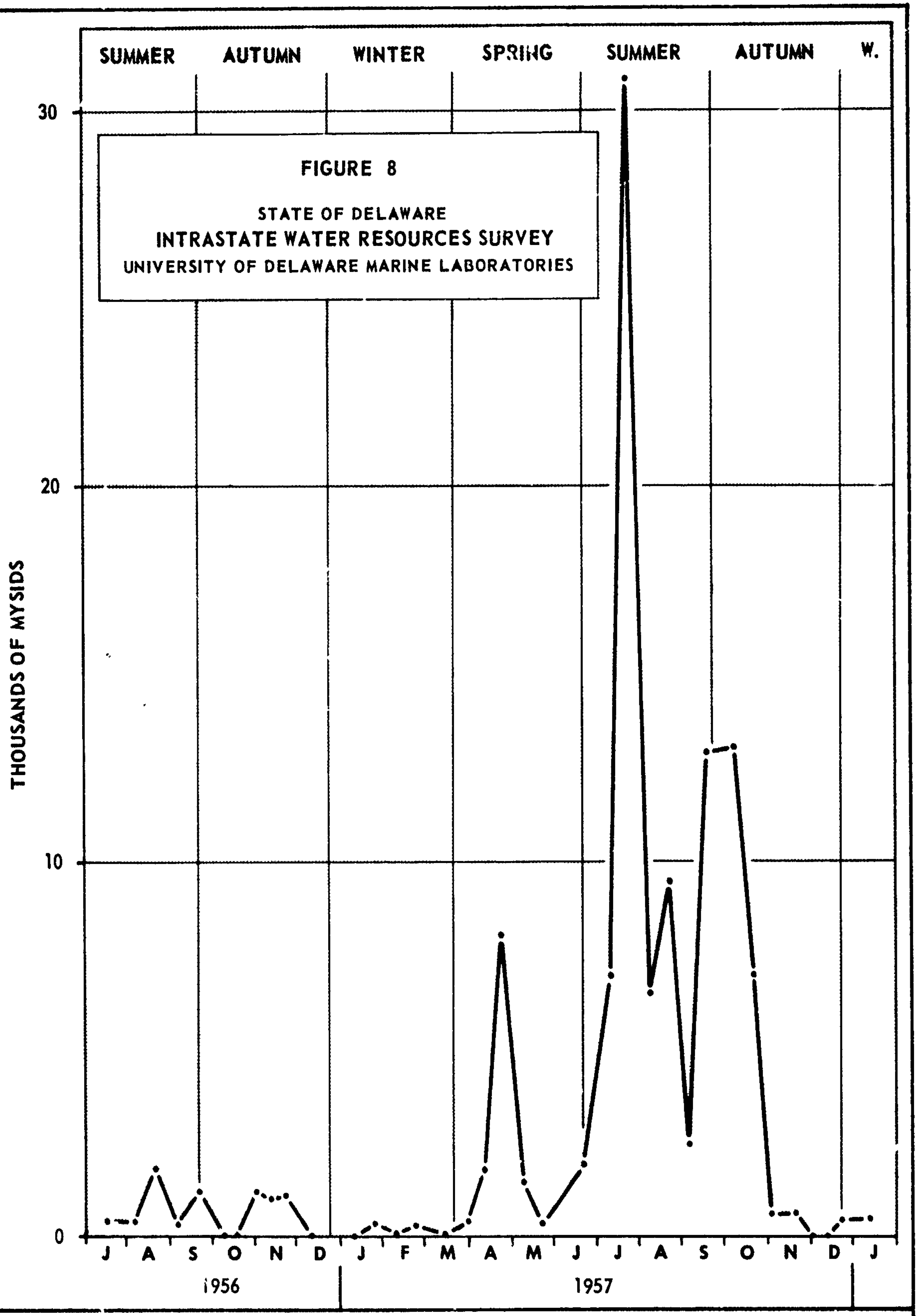
(?) Neomysis americana. This small shrimp-like crustacean is not only an abundant item in the diet of the weakfish, it is also eaten by spot, croakers, some flounders, and other commercially important fishes (personal communication from Dr. Franklin C. Daiber). It is also the most studied zooplankton species in the Delaware River estuary.

Hopkins (1958a) conducted a biweekly zooplankton survey at the Indian River Inlet over a 2-year period. During this time four species of mysids were found in the plankton but only two, Neomysis americana and Mysidopsis bigelowi, consistently contributed large numbers and bulk to the plankton. Mysidopsis generally reached its peak in abundance during the late fall and winter when it occasionally ranks first in the mysid population. On a yearly basis, however, Neomysis is the predominant species, contributing 90 percent of the mysids more than half of the time.

Though Hopkins (1958a) found that the mysid population varied from month to month (See Figure 8, page 21-42), day to day, and even from hour to hour, he collected voluminous evidence that this group of animals, at least locally, constantly ranked second in numbers and bulk in the total zooplankton, being exceeded only by the tiny copepod crustaceans. Data for a 12-month period at Indian River Inlet, summarized in Tables 14 and 15, shows that, exclusive of the copepods and occasionally comb jellies, mysids ranked first in number and volume of all the species that exceeded one millimeter (about one-sixteenth of an inch) in length 95 percent of the time. The mysids were over one-half of the total number of zooplankton species in three-fourths of the plankton collections, over half of the bulk in two-thirds of the collections.

Hulburt (1957) reported that Neomysis was much more abundant in the deep water of Delaware Bay during daylight hours than in the near-surface or shallow water, or in the coastal waters at the mouth of the bay. This difference from the observations of Hopkins can be explained on the basis of when the plankton collections were made, nighttime or daytime, since Hulburt (1957) attributed the fewer numbers of Neomysis in surface waters during daylight hours to their avoidance of excessive light. A change in the turbidity of the bay water could, therefore, affect the distribution of mysids. Beside the light intensity factor, Neomysis is further limited in its distribution by salinity. Hulburt (1957) found that its estuary extent was restricted by waters less than 4 °/oo. Thus, light intensity limits the vertical distribution of Neomysis, salinity its horizontal distribution in the estuary.

b. The estuarine environment. Among the ever-changing variables within an estuary, salinity is generally singled out as the key factor in



FLUCTUATION IN THE ABUNDANCE OF MYSIDS IN AN ESTIMATED 10,000-GALLON SAMPLE OF WATER, FROM 17 JULY 1956 TO 7 JANUARY 1958. DESPITE THE MARKED FLUCTUATIONS IN ABUNDANCE, MYSID SHRIMP CONSISTENTY RANKED SECOND AMONG ALL ZOOPLANKTON SPECIES. (MODIFIED FROM HOPKINS, 1958a)

in the distribution of organisms. That it is a key factor can not be disputed, but there are also many other important ecological factors such as currents, tides, silt, pollution, shoreline development, and geology. It may be more correct to use salinity as an index of the environment since salinity, indirectly probably can be related to, as an example, the silt load of the river discharge. Also, it would be difficult to consider the effect of the density of the bay water and of density currents upon the distribution of planktonic organisms if salinity and temperature of the water were not both considered. Since temperature influences the metabolism of cold-blooded animals, it would be impractical to consider only salinity as a factor in survival. Not only is it necessary to correlate many environmental factors and biological processes when considering the possibilities of survival for any species, but the duration of each factor is just as important to consider. When considering each factor and how it affects other phenomena and biological processes--in time and space, in quantity and quality--the average mind soon loses comprehension of the multidimensional aspects of the problems involved. These problems are best relegated to a team of researchers and a biomathematician.

In spite of our realization of the complexity of the interreactions of the several ecological factors and the several dimensions in which they may act, for brevity our emphasis will be placed upon salinity and pollution as two factors affecting the livelihood and distribution of estuarine organisms.

(1) Biological conservation of water. Their ability, or lack of it, to conserve the water and salt content of their cells, tissues, or body fluids under varying environmental salinity conditions determines to a large extent where aquatic organisms can survive. Only those organisms capable of maintaining some level of water and salts within their bodies can survive the changes of salinity which occur in an estuary. The manner in which the body fluids and salts are conserved varies in type and efficiency among the different species. Indeed, it is this species difference of tolerance or adjustment to various degrees of salinity that determines where a particular species may exist.

Species that are restricted by salinity in their downstream movements or habitation area are said to be held in check by a "salinity barrier." The reverse situation is due to a "fresh-water barrier." The important biological factor, in either case, is that the barrier is due to the inability of the organism to conserve or maintain its own water and salt supply. The real barrier, therefore, is an osmotic one.

(2) The osmotic barrier. Within a container partitioned into two wells, one containing fresh water and the other an equal volume of sea water, separated by a membrane through which water molecules will pass, the level of sea water will rise. This is due to osmosis, whereby water molecules tend to distribute equally within the volume available to them. Since there are proportionately fewer water molecules in sea water, due to the dissolved salts, than in the same volume of fresh water, the flow of water molecules is greatest into the sea water well until an equilibrium of flow is established. In an organism this flow of water into the body and tissues is much more complicated, but in our discussion our chief concern is the osmotic flow of water.

Figure 9 (page 21-45) illustrates the importance of osmotic flow of water as a barrier to the distribution of species unable to adapt or to adjust to the varying salinity conditions within an estuary. What happens to a freshwater organism, shown as a single cell for simplicity, that can not maintain its water supply in a sea water environment is illustrated in A and B of Figure 9. A species living in fresh water maintains its fresh water balance by secreting the excess water due to osmotic flow (A). When placed in sea water, if the able-to-live-in-fresh-water species can not control the now outward osmotic flow of water, it soon collapses.

The reverse situation, of a marine organism in fresh water, is shown in C and D. One way in which a marine species can maintain its water balance against the outward osmotic flow, is to drink the sea water and excrete salts (C). If unable to prevent the inward flow of water, when placed in fresh water, the marine organism bloats and dies.

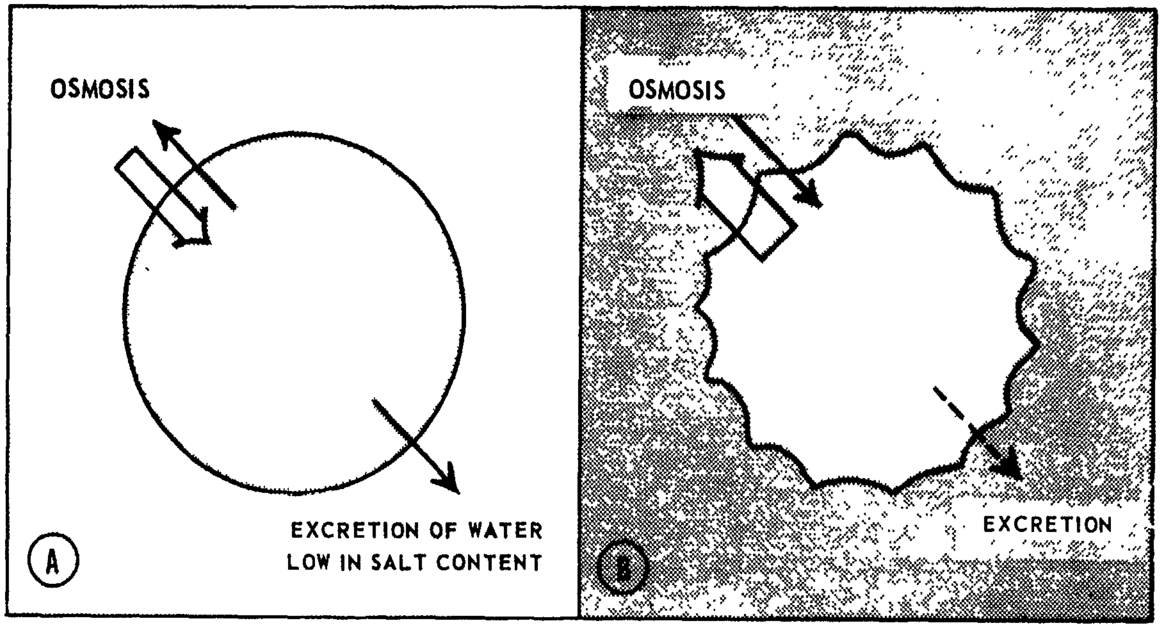
The above explanation and accompanying diagrams show the problem of water conservation faced by aquatic species; it does not give the reader an adequate impression of the many kinds of excretory and osmoregulatory (water-regulating) systems found among these species. Prosser (1950) gives an interesting, well-documented account of the importance of water conservation to organisms.

Each species living within the estuary has its own range of tolerance or adjustment to salinity change. This of course determines where they can survive. Some species can withstand gradual changes, as the shad and eels that migrate to and from fresh water and marine habitats. The ranges of salinity within which some estuarine invertebrates are reported to be able to survive are given in Table 16 (page 21-46). Differences between these species ranges may have economic importance.

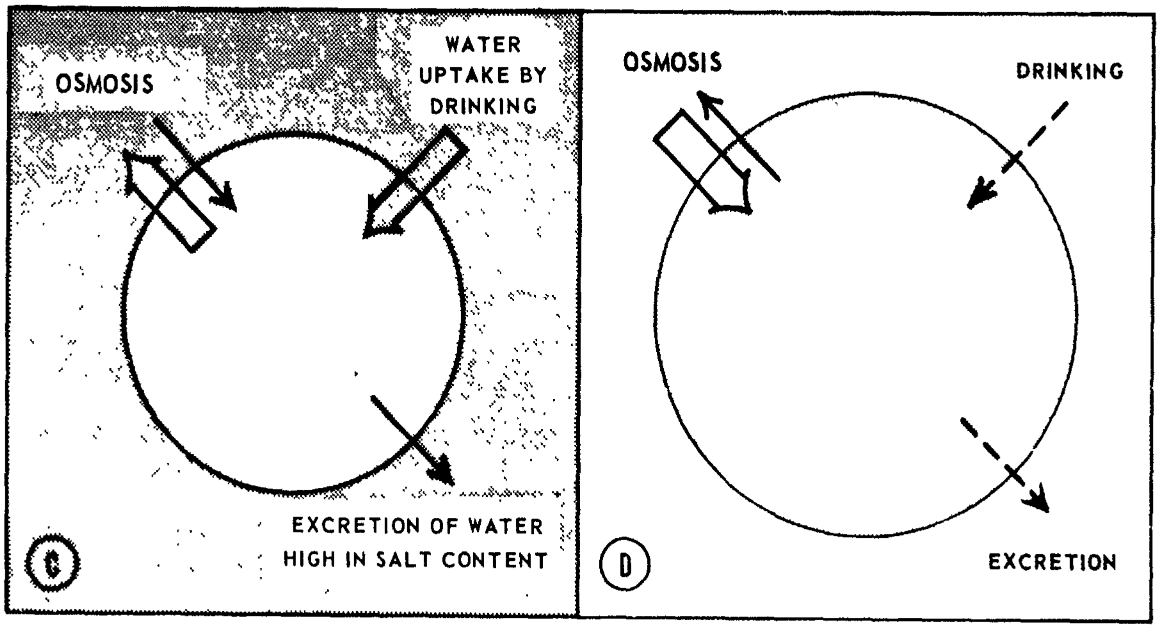
A notable example is seen in the prevention of the invasion by the oyster drill Urosalpinx cinerea onto the natural oyster beds in the upper bay region by a fresh water barrier. The drill is considered to be the most destructive predator on oysters in the upper portion of the Delaware estuary. This predation is heaviest upon spat and seed oysters.

There is another kind of evidence on the effectiveness of the osmotic barrier in estuaries. It has long been recognized that there are fewer species living in estuaries than in either fresh water or marine habitats. This small number of species seems to be directly related to the rigorous climate of the ever-changing estuarine environment. Few species can withstand, for example, the twice-daily salinity change that accompanies the tidal fluctuation. Those species that can survive, however, produce large populations. This abundance of a few species capable of living over a large area of the estuary has economic importance, as seen in the commercial shellfisheries harvest.

(3) Dangers of pollution. The harmful effect of pollution upon aquatic resources has long been recognized. Two major damages caused by pollution result from: 1) a change from the natural environment (see also Section XVIII and the Discussion Section) to one that is detrimental or lethal to aquatic organisms, and/or 2) a commercial loss because the sea food is unfit for human consumption.



A FRESHWATER SPECIES TAKEN FROM NATURAL CONDITIONS (A) AND PLACED IN SEAWATER (B) LOSES WATER AND SHRINKS.



A MARINE SPECIES TAKEN FROM NATURAL CONDITIONS (C) AND PLACED IN FRESH-WATER (D) GAINS WATER AND SWELLS.

DIAGRAMMATIC REPRESENTATION OF THE EFFECT OF OSMOTIC FLOW OF WATER UPON A FRESHWATER SPECIES (A AND B) AND A MARINE SPECIES (C AND D) UNDER USUAL AND EXTREME CONDITIONS.

FRESHWATER

FLUID CONTENT OF ORGANISM

SEAWATER

SIZE OF ARROWS INDICATES EXTENT OF WATER FLOW

FIGURE 9

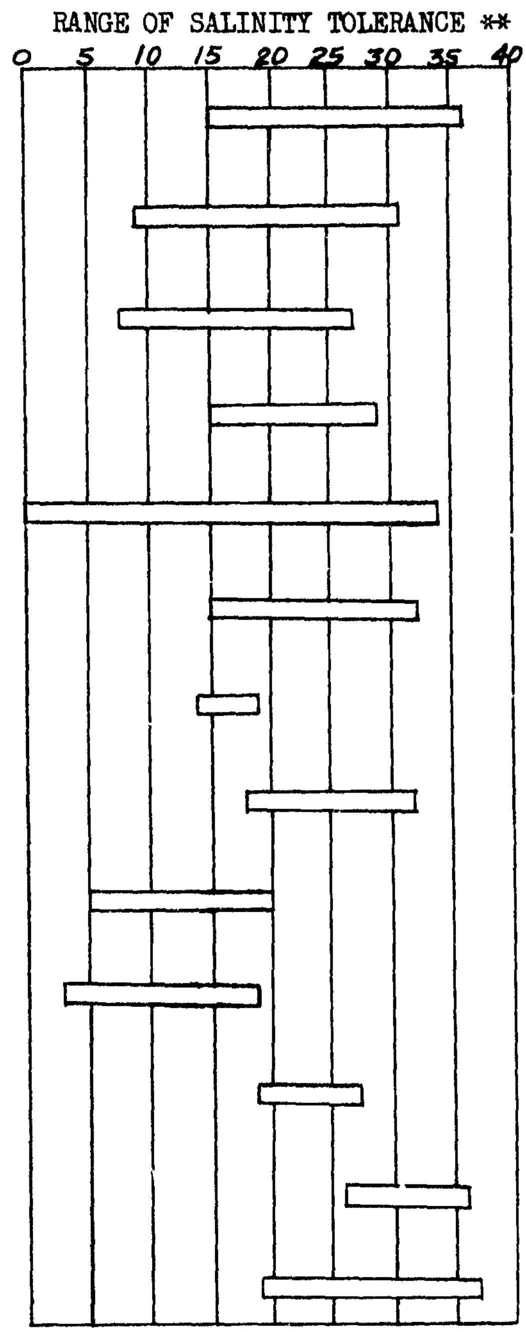
STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
UNIVERSITY OF DELAWARE MARINE LABORATORIES

TABLE 16

SALINITY TOLERANCES OF SOME INVERTEBRATES
OCCURRING WITHIN THE DELAWARE RIVER ESTUARY

(Compiled from several sources)

*	ORGANISMS
(1)	*Cliona celata* (boring sponge)
(2)	*Nereis succinea* *** (a clamworm)
(1)	*Crassostrea virginica* **** (Atlantic oyster)
(3)	*Urosalpinx cinerea* ***** (oyster drill)
(1)	*Callinectes sapidus* (blue crab)
(4)	*Neopanope texana sayi* (Say's mud crab)
(5)	*Panopeus herbsti* (a mud crab)
(4)	*Hexapanopeus angustifrons* (a mud crab)
(5)	*Eurypanopeus depressus* (flat mud crab)
(5)	*Rhithropanopeus harrisi* (brackish water mud crab)
(2)	*Aeginella longicornis* (long-horned caprellid)
(1,6)	*Loligo pealii* (common squid)
(1)	*Lolliguncula brevis* (short squid)



* = Sources: (1) Spector, 1956; (2) Amos, 1954 and unpublished data; (3) Carriker, 1955; (4) Cowles, 1930; (5) Ryan, 1956, and (6) Haefner, 1959.

Continued on next page.

** = Stauber (1954) pointed out, in discussing a graphic method of representing salinity condition in Delaware Bay, that species are limited to certain regions of the estuary by the effects of the extremes in the salinity range and of their duration rather than by the average conditions. For a further discussion of tolerances see Fry (1947).

*** = At summer temperatures (20° to 27°C).

**** = Can withstand short-time salinity changes of 0 to 42 °/oo in the laboratory (1).

***** = Can survive salinities as low as 8 °/oo during the winter (2).

Shellfish, due to their sedentary nature, are especially susceptible to pollution. Many research reports document this fact. Baughman (1948) lists over 65 such reports and many more have been completed since then.

Among the early dangers of pollution in the Delaware Bay were oil from mosquito ditches, waste oil from steamships, industrial chemical wastes, and excessive sewage. To these can be added the modern array of household and agricultural chemicals: detergents, insecticides, and herbicides. Artiffcial radioactivity due to atomic explosions or radioactive wastes pose an even more serious problem (see also Section XVIII) because aquatic organisms, particularly shellfish, accumulate these radioactive substances within their tissues.

During the last half-century the oyster harvest of the United States has steadily declined to about one-half of its former volume. Galtsoff (1956) attributes this decline to pollution resulting from the increase in population and accompanying industrialization.

21.08 EVALUATION OF THE DELAWARE RIVER ESTUARY FISHERIES

This section is intended as a summary of the fisheries of Delaware, commercial and sport, and as a report upon the dollar value of the fisheries crops harvested from the Delaware River estuary and of the fisheries based upon these crops.

a. Shellfisheries in Delaware Bay. There are three large shellfisheries located in Delaware Bay: two for mollusks, the eastern American oyster (Crassostrea virginica) and the northern quahog (Mercenaria mercenaria) and one for a crustacean, the blue crab (Callinectes sapidus).

The information contained in this subsection is an approximation of both the economic value of the shellfisheries and the dollar value of the shellfish harvest areas in the western side of Delaware Bay. Another aspect of this section will be to point out the regions of Delaware Bay that seem to be more productive, in terms of shellfish harvested, than other areas of the bay. By establishing the extent of the more productive shellfish areas, researchers can direct their efforts toward determining the cause of high productivity in these particular areas and toward giving more positive conservation advisement.

(1) Method of study. Catch statistics data were related to actual fishery areas. The harvest data were taken from the most recent issues of "Fishery Statistics of the United States," published by the Fish and Wildlife Service, United States Department of the Interior. The total harvest for the 7-year period from 1950-1956, was averaged to obtain the value of the mean annual landings. These shellfish landings are given in pounds and dollar values at the dock.

The recorded price per pound is the average amount paid to the fishermen for their harvest, alive, at the dock. This price, obviously, is subject to wholesale and retail increases before it reaches the ultimate consumer.

Harvest data were compared with the shellfisheries areas plotted on U.S. Coast and Geodetic Survey Chart #1218. The extent of fishery areas, determined by our general knowledge of the bay and by personally interviewing the local commercial fishermen, is depicted in Figure 10, page 21-49. Measurement of the size of these areas was made by the method described previously on page 21-6.

(2) Oyster fishery. The major portion of the oyster fishery in Delaware Bay is a privately managed industry using the dredge method of harvest. A few oysters are tonged in the tidal creeks, but these landings are insignificant. The oyster harvesting season starts on September 1 and lasts through April; it is discontinued during the summer months when oysters spawn.

The industry is comprised mainly of individual oystermen who lease Delaware Bay bottom from the State. Rental is paid by the acre and varies from $.75 to $2.00 per acre. Young oysters are planted upon these leased grounds to grow and fatten for market. These young oysters are called seed oysters, and, prior to 1951, were obtained largely from the natural seed beds area of Delaware Bay. Since then many oystermen have bought "seed" from the seaside waters of Virginia. These seed oysters are planted (dumped overboard) on the rented acres and left to grow for one to four years. On some oyster bottoms (grounds), market size oysters can be harvested $1\frac{1}{2}$ years after the "seed" has been planted; in other areas, 3 or 4 years.

In the western portion of Delaware Bay there are 45,000 acres of oyster grounds available for private planting, but usually only about 20,000 acres are leased. The 6,000 acres in the natural seed beds area, although presently nonproductive, are potentially the best source of seed oysters for replanting the leased grounds.

Decline of the natural seed beds of Delaware was analyzed by Shuster (1957). During the 12-year period recorded in Table 17, page 21-50, the total number of bushels of shells and oysters planted was 686,000; whereas 2,961,000 bushels were removed. The high level of seed production on the natural beds during the years from 1945 through 1949, was suddenly curtailed by a heavy mortality of the young oysters during the summer of 1950. Even without the mortality, it is doubtful that the annual production of 150,000 bushels of seed oysters could continue if there were not: sufficient shells on the bottom to catch the young oysters, a large spawn-

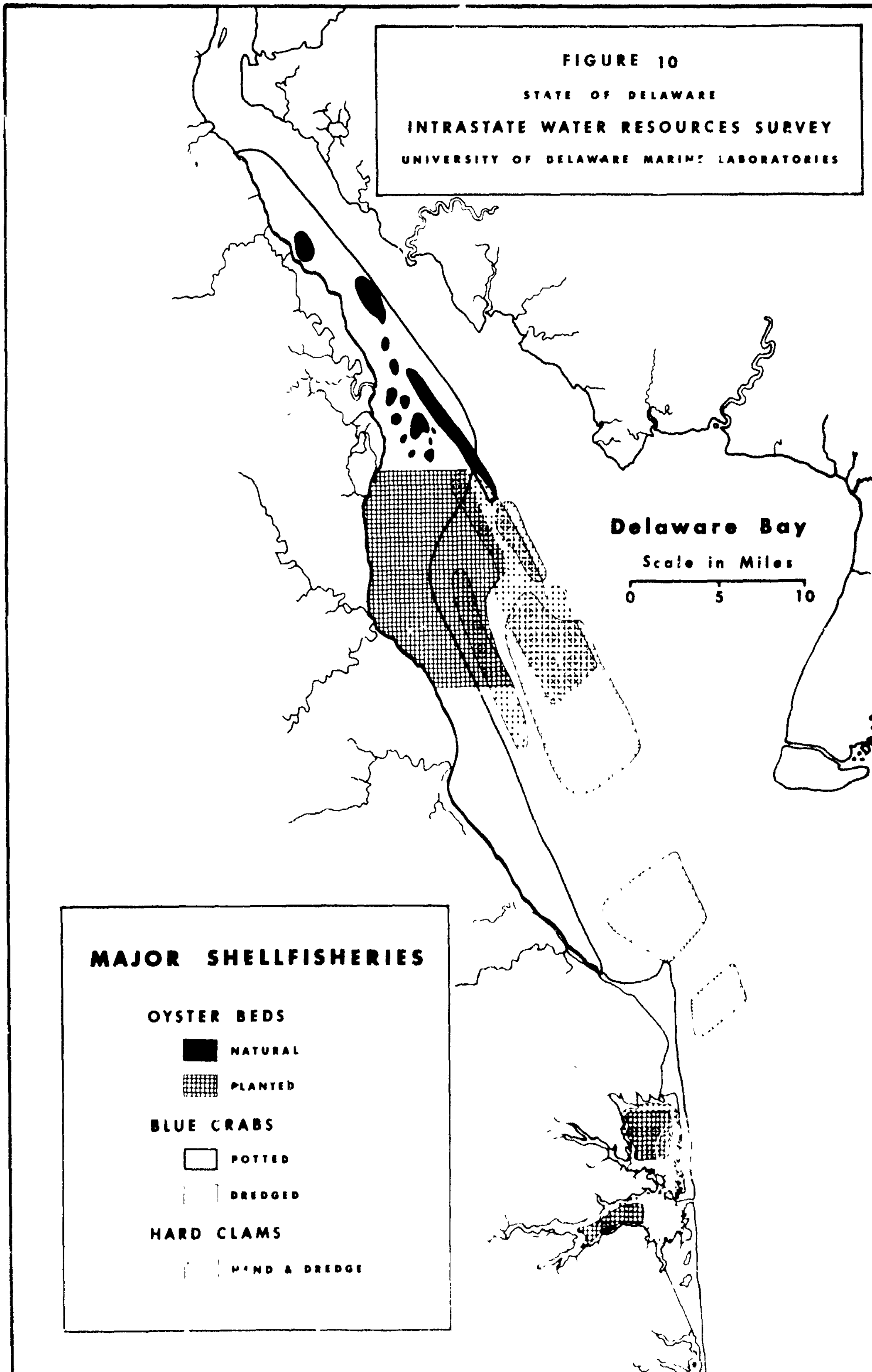


FIGURE 10
STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
UNIVERSITY OF DELAWARE MARINE LABORATORIES
Delaware Bay
Scale in Miles
0 5 10
MAJOR SHELLFISHERIES
OYSTER BEDS
NATURAL
PLANTED
BLUE CRABS
POTTED
DREDGED
HARD CLAMS
HAND & DREDGE

ing population, and environmental factors favorable to setting of young oysters. Today the natural beds are barren. This is not the first time that production was low on these beds; it also occurred during the early 1900's and in 1942. Recovery was slow in the first instance, rapid in the 1940's. Rehabilitation of these beds is possible but it will be an unusually difficult task today because the oysters of Delaware Bay have suffered another widespread mortality (Shuster, 1958).

TABLE 17

QUANTITY (IN THOUSANDS OF BUSHELS) OF SHELLS AND SEED OYSTERS PLANTED UPON OR REMOVED FROM THE NATURAL SEED BEDS OF DELAWARE

Year	Oysters Planted	Shells Planted	Oysters Removed	Shells Removed
1946	-	-	125	375
1947	-	25	144	431
1948	-	50	150	450
1949	-	100	163	487
1950	-	200	106	319
1951	-	78	75	25
1952	-	90	38	13
1953	-	55	15	5
1954	7	41	15	5
1955	-	40	14	5
1956	-	-	1	-
1957	-	-	-	-
	7	679	846	2,115

This new wave of mortality, starting within the planted grounds of New Jersey in 1957, has not yet run its course. Although the pattern of the spread of the mortality is similar to that of a contagious disease over an ever-widening area, the cause is not yet known. The evidence indicates that a microscopic enemy has invaded the tissues of the oysters. Questions concerning the origin of the mortality, what causes it, and how it is spread are unanswered. There is the possibility that the enemy was favored by a change in the environment. This change might have been caused by something like the rapid buildup of detergents in the river water in the past ten years, but the fact is, little is known about the subtle changes that man has caused in the estuarine environment and what their effect might have been upon estuarine life. Much research needs to be done to remove this blindfold of ignorance.

During the 7-year period analyzed, the Delaware oyster industry harvested an average of 2,639,581 pounds of oyster meats each year with an average value of $1,360,207 per year. This is an average harvest value of 51 cents per pound of meats, which is equivalent to $3.06 a bushel for oysters in the shell, since about 6.0 pounds of oyster meats are shucked from a bushel of live oysters. These values of the oyster crop are augmented by the wholesale and retail values. One scale of wholesale prices

of fresh shucked oysters is given in the following table, which reflects the cost of labor to shuck and package the harvest for market. By comparison, the current (1959) retail price in one chain store in Delaware, based upon $1.19 per pint, is $9.52 per gallon for standards. A gallon of retail packed standards weighs 9 pounds.

TABLE 18

THE WHOLESALE PRICE OF FRESH OYSTERS

Designation	Number per Gallon	Wholesale Price Per Gallon 1956	1957	1958	1959
Standard (Stewing)	350	$5.75	$6.25	$6.25	$6.25
Select	240	6.50	7.00	7.00	7.00
Extra-select	180	7.00	7.50	7.50	7.75
Counts	135-145	7.50	8.00	8.25	8.50

TABLE 19

AVERAGE ANNUAL OYSTER LANDINGS IN DELAWARE DURING 1950-1956

County	Average Oyster Harvest Pounds	Value
Kent	19,953,290	$1,006,415
Sussex	686,291	353,792
	20,639,581	$1,360,207

These values give an indication of the magnitude of the harvest for each county. Nearly all the rented oyster grounds are in Kent County; there are none in the waters of New Castle County, and only a few thousand acres in Sussex County.

(3) Hard clam fishery. The northern quahog is known locally as the hard clam. In Delaware Bay these clams are dredged during the winter. In Rehoboth Bay and Indian River Bay hard clams are tonged throughout the year.

During 1950-1956, an average of 629,143 pounds of meats was obtained from the hard clams harvested each year. The clammers received an average of $207,616 a year for their harvest. Since there are about nine pounds of clam meats in a bushel of live clams, and the average price paid for clam meats was 33 cents per pound, the harvest value of a bushel of

clams is nearly $3.00. The wholesale and retail value of these clams, obviously, would be greater.

Most of the 23,000 acres of clam harvest grounds in Delaware Bay are in Kent County, where landings averaged 331,243 pounds a year of clams valued at $111,672. The average harvest from these Kent County clam grounds was 1.66 bushels per acre; a $5.00 harvest of clams per acre.

The Sussex County hard clam fishery in Rehoboth and Indian River Bays is included in this survey because these bays are influenced by the offshore estuarine waters. A large volume of Delaware River-diluted oceanic water moves into these bays on every flooding tide, markedly changing the hydrographic and chemical conditions there (Shuster, 1957). The fishery extends over some 17,000 acres in these bays and continues throughout the year by tong and rake methods of harvest.

The Sussex County average yield has been 297,000 pounds of meats a year with an average annual value of $423,800. These clams were valued at $1.42 per pound, four times that of the Kent County product. This difference is due to the size and use of the clams: small ("cherrystone") clams are steamed or used as half-shell stock, and the larger ("chowder") clams are used in soups and chowders. The average of 17.3 pounds of clam meats produced by each acre of clam beds was also higher than the 15 pounds per acre in Delaware Bay, and the average yield of clams per acre in Sussex County waters was worth $25.

(4) The blue crab fishery. The blue crab fishery is conducted throughout the year and moves about, following a regular sequence of areas in Delaware Bay. This shifting scene of the fishery is due to the seasonal migration and maturation of the crabs (Porter, 1956). Crabs are potted near shore in the lower portions of the bay during the early spring, and toward summer, as the water warms up, the fishery moves up the bay along the shore. By September most of the larger crabs are in the upper bay region. As winter approaches, the adult population moves down-bay toward the higher salinities. They remain quiet and "bed down" in the soft bay bottom, commonly on the shoal bars in 10 to 40 feet of water.

Crab dredging begins on December 15, and continues until early spring when the crabs move off the bars and begin the up-bay migration. Oyster schooners, party boats, and fish trawlers are outfitted with crab dredges for this work.

Blue crabs are not potted during the fall because of a slack market. This slack market for crabs is generally marked by the advent of the oyster season in September, when the crab-picking houses supplied by the potters temporarily shut down because most of the labor turns to oyster shucking. Market-sized crabs, however, are plentiful and in good condition and are commencing their annual down-bay migration to the mud flats at this time.

Commercial crabbing in Delaware Bay can be a very profitable business. The price that a crabber receives for a bushel of crabs fluctuates with the season and the abundance of crabs. During the summer the price for #1 grade crabs, large males, is $5 to $7 a bushel; #2 grade crabs,

any medium-sized males and all females, bring $1.50 to $3.50 a bushel. The smaller males and the females, due to their size, are less valuable to the crab picking-house markets. The winter catch of mixed crabs, mostly females, is sold by the barrel for $8 to $18 a barrel---depending upon the abundance of crabs and the market condition. Many crabbers pot from 20 to 30 bushels of crabs every day of the summer; winter crabbers may dredge from 5 to 15 barrels a day.

The average yearly crab catch in Delaware Bay for the 7-year period studied was 3,143,700 pounds, or 7,869,250 crabs for which crabbers were paid $294,163. On the basis of these averaged figures, Delaware Bay crabs bring 10 cents a pound, or, each crab caught was worth 3.3 cents.

TABLE 20

AVERAGE ANNUAL CRAB LANDINGS
BY DELAWARE COUNTIES
1950-1956

County	Pounds	Value
New Castle	213,871	$ 21,295
Kent	2,695,486	248,640
Sussex	234,343	24,228
	3,143,700	$294,163

These county harvest records do not reveal exactly where the crabs were caught, but they do indicate that Kent County boats account for five-sixths of the average crab landings in Delaware Bay.

The combined area of the crab pot fishery (85,000) and the crab dredge fishery (44,000) is 129,000 acres. The average yearly harvest records show that 25 pounds of crabs, worth $2.50, are harvested per acre per year. This is an average of one bushel, or 62 crabs, harvested per acre per year.

(5) Summary of shellfisheries. The extents of the areas given in Table 21, page 21-54, are approximations. An attempt was made to outline the boundaries of the major areas of shellfisheries harvest, as indicated on Figure 10. An evaluation of the regions of greater harvest within each area was not ascertained. We know that production was not equal throughout the entire area; therefore, crop values per acre computed from the table give an erroneous impression of actual values. The table is useful, however, since it establishes data from which certain inferences can be made more easily. For example, less than one-half of the 45,000 acres outlined as planted oyster grounds are suitable for planting. Actually, the annual oyster crop of over one million dollars has been harvested from about 8,000 of a total of some 20,000 planted acres. The annual harvest is worth some $170 per acre, but this is obviously an average estimate of oyster production per unit of area, since oysters are not uniformly abundant even in the planted areas.

TABLE 21

SUMMARY OF SHELLFISHERIES, 1950-1956

(All values and measurements are recorded in thousands.)

Area Described	Size of Area (In Acres)	Average Crop Harvest (Pounds)	(Value)
Western portion of Delaware Bay (See Table 1 (B), page 21-9)	197		
Extent of bay bottom including all shellfisheries areas	170		
Extent of planted oyster grounds	45	20,640	$1,360
Clam dredge fishery	23	331	112
Clam tong and rake fishery	17	298	424
Crab pot and dredge fishery	129	3,144	294
Total of shellfisheries areas	214*	24,413	$2,190

* This figure is larger than the actual bottom area utilized by the shellfisheries (170,000 acres) because there is some overlap of the individual harvest areas (see Figure 10).

It is certain, therefore, that the annual crop harvest value of $10 per acre, derived from the 170,000 acres within which shellfish harvests are taken, is too low an estimate. Assuming that production throughout one-fifth of the total area is equivalent to the average oyster production level, then the bulk of the harvest is being produced upon 43,000 acres. This gives an average harvest value of $50 per acre, but even this estimate may be only one-tenth or less of the actual production that does occur. Harvest rates and total biological production are widely different, since even for the oyster large populations capable of restocking the beds must be maintained.

Calculating with $2,190,000 as a 5 percent return, this annual harvest of shellfish represents a dividend upon an investment of $43,800,000; or an evaluation of $1,000 per each heavily harvested acre.

b. Commercial and sport fisheries in Delaware waters. An evaluation of the magnitude of the sport fishery has been made by the University of Delaware (Daiber, 1956). This evaluation, with data obtained from "Fishery Statistics of the United States," for the years 1950-1956, has been utilized to determine the major Delaware fishing areas and to assign catch data and the value of catches to these areas.

(1) Sources of information. The first portion of this section is directed toward an evaluation of commercial fisheries in the State of Delaware. The yearly value of the fish catch, in pounds and dollar value, was derived from the "Fishery Statistics of the United States" and compiled into Table 22.

Areas of the estuary most frequently commercially fished were located by analyzing available catch records and unpublished information. These areas were plotted on U.S. C.&G.S. Chart #1218 and then measured, in acres, using a compensating polar planimeter. The catch value, divided by the acres of fishing grounds, gives a per-acre evaluation of the commercial fisheries. This value represents an annual return on a capital investment and indicates the worth of the area of the estuary used for commercial purposes. Commercial fishery methods analyzed include the following: purse seine, haul seine, gill nets (anchor, drift, runaround, and stake), fyke nets, dip nets, and otter trawls. The data for the areas illustrated in Figure 11 are given in Table 23.

TABLE 22

ANNUAL ESTIMATE OF THE FISH CATCH
IN THOUSANDS OF POUNDS AND DOLLARS
FOR EACH DELAWARE COUNTY

(Compiled from U.S. Fish and Wildlife Service "Fishery Statistics," 1950-56)

	NEW CASTLE		KENT		SUSSEX		TOTAL DELAWARE	
Year	Lbs	$	Lbs	$	Lbs	$	Lbs	$
1950	103	16	301	50	152,848	1,665	153,252	1,731
1951	129	21	326	55	167,355	2,014	167,810	2,090
1952	200	24	154	34	208,243	2,067	208,597	2,125
1953	187	25	156	39	361,798	4,057	362,141	4,121
1954	155	17	194	26	307,111	4,564	307,460	4,607
1955	160	8	1,248	106	308,923	4,221	310,331	4,335
1956	54	4	675	54	353,709	4,678	354,438	4,736
Avg.	141	16	436	52	265,712	3,324	266,289	3,392

TABLE 23

AREAS OF COMMERCIAL TRAWL AND NET FISHERIES
(See Figure 7)

TRAWL FISHERY		NET FISHERY	
Area	Acres	Area	Acres
T-1	3,200	N-1	700
T-2	7,500	N-2	1,200
T-3	3,600	N-3	400
T-4	14,800	N-4	10,100
T-5	2,200	N-5	400
Total acres	31,300	Total acres	12,800

An intensive survey of the salt water sport fisheries, sponsored by Dingell-Johnson funds allocated for marine fisheries research by the Delaware Board of Game and Fish Commissioners, was conducted by the University of Delaware in 1953 and 1954. This survey included fishing of the following types: 1) party boat fishery, 2) row boat fishery in Delaware Bay, 3) surf fishing, 4) jetty fishing, and 5) wharf and bridge fishing. Information on the number of sport fishermen in an average year for each of these types of fishing is summarized in Tables 25 and 26. This average year number of sport fishermen and the average amount of money spent per salt water fisherman (Circular 44, published in 1956 by the U.S. Department of the Interior on a "National Survey of Fishing and Hunting," conducted in 1955) gives the estimated dollar value of the sport fisheries to the State of Delaware.

(2) Commercial fisheries of Delaware Bay. An average year commercial catch and catch value was computed from the available recent (1950-1956) "Fishery Statistics of the United States." Table 24 records the commercial species of fishes. Table 22 gives an average year catch of 266,-289,000 pounds of fish from the Delaware Bay area, with the 7-year average value of $3,392,000. The menhaden fishery contributed the bulk of these averages with 264,821,000 pounds and $3,234,000 yearly. Table 23 and Figure 11 record and show the principal areas available to the net and trawl fisheries; a total of 44,100 acres. The value of the average yearly catch of these two fisheries, $158,000, divided by the acreage gives a per-acre value of $3.59. Assuming a 5 percent return, the annual catch then represents a profit on an investment of $3,160,000.

(3) Sport fisheries. The summary of marine sport fishing in Delaware contained in Section 20.06 is hereby, by reference, made a part of this section (21.08). The data presented in Table 5, on page 20-16, clearly establishes a large out-of-state segment of sport fishermen (54.1 percent from Pennsylvania, 12.6 percent residents of other states). This influx of anglers will travel to fish for food and/or pleasure.

On the basis of 21 airplane counts, made on randomly selected days of people fishing and knowledge of the probable percentage of people fishing on the day of the counts, as determined by other surveys, a cumu-

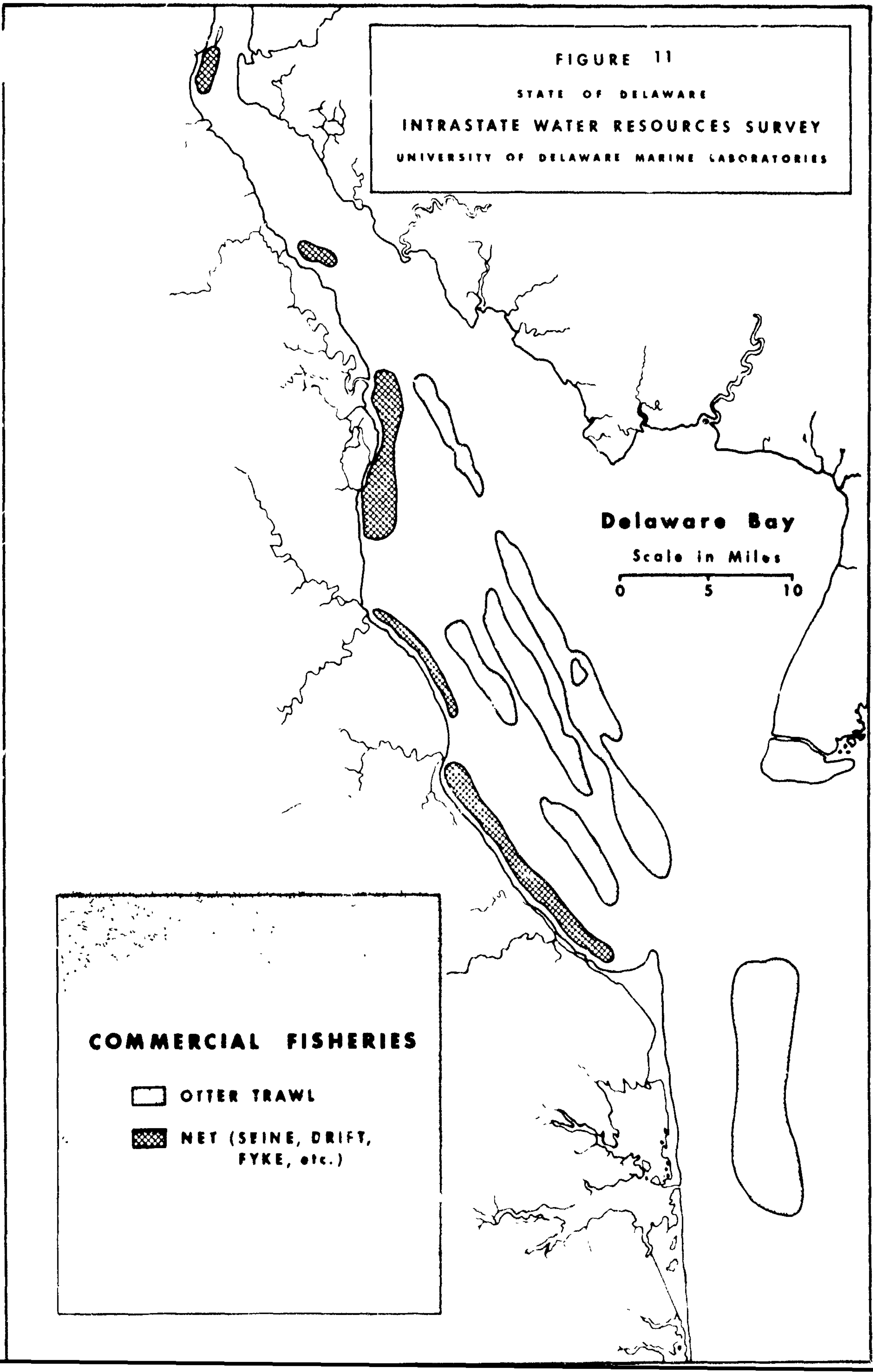


FIGURE 11

STATE OF DELAWARE

INTRASTATE WATER RESOURCES SURVEY

UNIVERSITY OF DELAWARE MARINE LABORATORIES

TABLE 24

A LIST OF THE FISH AND SHELLFISH HARVESTED FROM DELAWARE BAY
(Based upon "Fishery Statistics of the United States")

Common and Scientific names

FISHES

Alewife
Pomolobus pseudoharengus
Bluefish
Pomatomus saltatrix
Bonito
Sarda sarda and
Euthynnus alletteratus
Butterfish
Poronotus triacanthus
Carp
Cyprinus carpio
Catfish
Amerius (Ictalurus) species
Croaker
Micropogon undulatus
Drum (black)
Pogonias cromis
Eels, common
Anguilla rostrata
Flounder
Pseudopleuronectes americanus
Fluke
Paralichthys dentatus
Glut herring
Pomolobus aestivalis
Hake
Urophycis chuss
Herring
Clupea harengus
Ling
Urophycis regius
Kingfish
Menticirrhus species
Mackerel
Scomber scombrus

Menhaden
Brevoortia tyrannus
Mullet
Mugil curema
Mugil cephalus
Porgy
Stenotomus chrysops
Puffer
Spheroides maculatus
Red Drum
Sciaenops ocellata
Sea Bass
Centropristes striatus
Shad
Pomolobus sapidissima
Sharks
Carcharodon species,
Mustelus species,
Carcharhinus species,
Sphyrna species,
Lamna species and others
Spot
Leiostomus xanthurus
Striped Bass
Morome saxatilis
Sturgeon
Acipenser sturio
Trout
Cynoscion regalis
Cynoscion nebulosus
White perch
Morone americana
Whiting
Merluccius bilinearis
Yellow perch
Perca flavescens

(Table continued on next page.)

(Table 24 continued)

SHELLFISH

Blue crab	Maninose
Callinectes sapidus	*Mya arenaria*
Hard clam	Oyster
Mercenaria mercenaria	*Crassostrea virginica*
Conchs	Squid
Busycon canaliculatum	*Loligo pealei*
Busycon carica	

TURTLE

Snapper
Chelydra serpentina

lative total of 341,300 anglers during 1955, was estimated. This figure undoubtedly includes persons counted more than once, since Daiber (1956) found that, on the basis of over 1,900 interviews, 4 percent of the people interviewed were fishing for the first time, 28 percent had fished occasionally that season, while 68 percent of the anglers fished frequently. Even if only one-tenth of the estimated total represented different people, then at least 34,000 anglers fished in Delaware waters during the summer of 1955.

The national survey conducted for the Fish and Wildlife Service (Circular 44, *op. cit.*) reported that salt water anglers spent, on the average, $91.18 per year, 98 percent of which included equipment and trip expenditures. This means that the people fishing in Delaware waters spent some $3 million in pursuit of that fishing. The conservativeness of this estimate (given in the University of Delaware Marine Laboratories *Biennial Report*, 1955-1956, No. 3:11) can be demonstrated by another calculation. The $3 million represents only 1 percent of the total Atlantic Coast sport fishery, from Maine to Florida (according to data in Circular 44, *op. cit.*). We feel confident, therefore, that our estimate is a minimum value.

Referring to Table 6, page 21-25, and using our estimate above, during the summer of 1955 some 34,000 people fished a total of 1,594,100 hours, which is an average of 47 hours per angler per year. The table also records the prominent species of fishes, the number caught of each species, and the grand total of 2,618,700 fishes caught. Since edible fish landed by commercial fishermen were valued in 1955 at an average of 12 cents per pound, the sport catch, computed on the basis of one pound per fish, was worth $314,244.

The sport fisheries are not limited to specific areas as are the commercial fisheries. Party boat and row boat fishing are shown in figure 12. A more elaborate, pictorial chart of sport fishing areas was published in 1952 by Stevenson. Another was drafted by Mr. Anthony J. Florio to show the major access routes to inland lakes, primary streams, bay, and oceanside ports (published in January 1955 by the Delaware Board

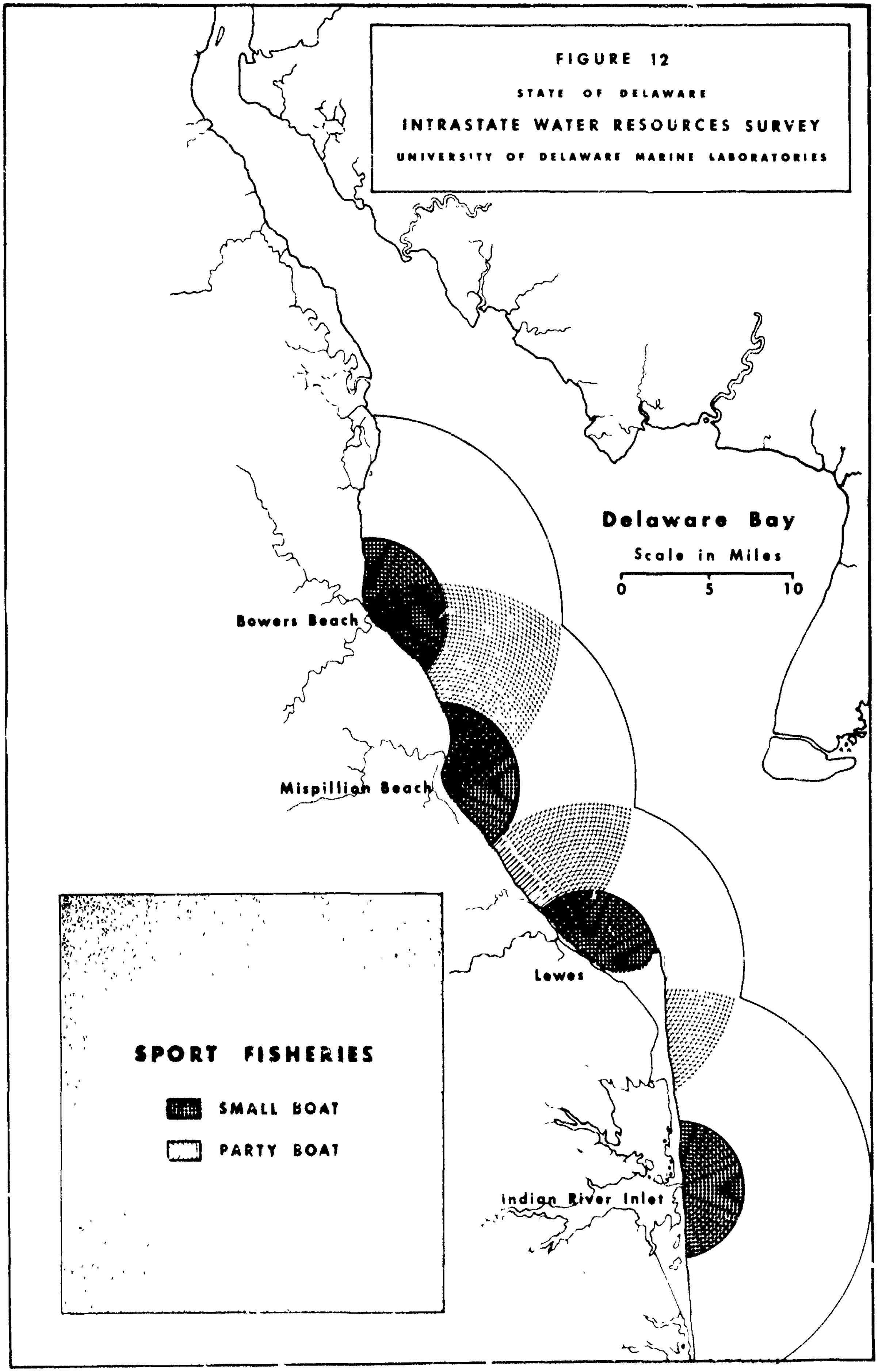


FIGURE 12
STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
UNIVERSITY OF DELAWARE MARINE LABORATORIES
Delaware Bay
Scale in Miles
0
5
10
Bowers Beach
Mispillion Beach
Lewes
Indian River Inlet
SPORT FISHERIES
SMALL BOAT
PARTY BOAT

of Game and Fish Commissioners). Practically all of the 197,000 acres in the Delaware or western portion of Delaware Bay (see Table 1, page 21-8), can be designated as a sport fisheries area. This is an oversimplification, however it suffices for the calculation to follow. Most of the beach areas, jetties, and bridges are readily accessible by good roads. The major small-boat ports are on or near major highways. This general accessibility suggests that the $3,314,244 per year value associated with the sport fishery in the above discussion can be equated to the entire 197,000 acres of water available to the anglers, or an evaluation of some $16.80 per acre per year.

The previous discussion has revolved about fishing as a form of outdoor recreation and a self-satisfying means of providing freshly-caught food for the table. There is also a considerable sport fishery for the blue crab and the hard clam, principally in the Rehoboth Bay and Indian River Bay areas.

Stevenson (1952) and Daiber (1954) reported upon sport crabbing and clamming in these bays for the summers of 1952 and 1953, respectively. The exact number of people enjoying this sport is not known, but an estimate is included with the other data combined from Stevenson (1952) and Daiber (1954) in Table 25. During two 12-week periods, the summers of 1952 and 1953, an estimated 252,040 blue crabs and 614,600 hard clams were obtained. The commercial value of this harvest averaged $15,692 per year, calculating the value of crabs at 3.3 cents apiece and assuming an average of 250 clams per bushel. Although of low economic value, this quantity of sea food provided 88,500 hours of recreation to several thousand sport crab and clam fishermen in 1952.

A spot check conducted in Rehoboth and Indian River Bays by wardens of the Delaware Commission of Shell Fisheries during the summer of 1957, revealed that an average of 250 persons clammed on week days, while 400 clammed on weekends and on holidays. The average harvest was found to be 100 clams per person. Assuming that these data are fully applicable over the four-month period commencing in mid-May, then over 1 million clams could have been harvested by sport clammers in 1957.

A comparison of the results of the 1957 spot check with those obtained during the 1952-53 surveys does not reveal if there was an actual three-fold increase in the harvest or whether there was a difference in the methods employed to survey the clammers. There also could have been an increased popularity of the sport, with more people doing more clamming than in the previous years. It can be easily confirmed on any summer weekend, however, that sport clamming and sport crabbing too, are real recreational activities enjoyed by entire families.

c. Ocean fisheries off Delaware Bay. The coastal region off Delaware Bay is one of the most productive ocean fisheries areas in North America according to June and Reintjes (1957). They estimated that during 1953, a total yield of fish and shellfish from this region amounted to over 662 million pounds, valued at $11.5 million to the fishermen. This production could be much higher because many millions of pounds of trash (not utilized) species of fish are discarded annually.

TABLE 25

SUMMARY OF A SURVEY OF SPORT CRABBING AND CLAMMING IN INDIAN RIVER BAY AND REHOBOTH BAY DURING THE SUMMER OF 1952

(Based upon data obtained by Stevenson, 1952, with an estimate of the harvest in 1953 from Daiber, 1954.)

SPECIES	NUMBER OF SHELLFISH CAUGHT	NUMBER OF FISHERMEN	HOURS SPENT FISHING	AVERAGE CATCH PER HR.	ORIGIN OF FISHERMEN Del.	Other
Blue crab	166,000 (1952) 86,040 (1953)	10,350	45,000	4	30%	70%
Hard clam	300,800 (1952) 313,800 (1953)	11,325	43,000	7	30%	70%

June and Reintjes (1957) surveyed the ocean fisheries in an area of some 11,236 square miles (statute) along the Atlantic Coast between Barnegat Lightship and Winter Quarter Lightship, seaward to the 100 fathom contour. They stressed the large number of commercial and other species occurring off Delaware Bay. This area is more or less the geographical center of migratory fishes, as weakfish, croaker, sea bass, and porgy, which range in abundant numbers principally between Cape Cod and Cape Hatteras. It is the southernmost extent of many northern species, such as cod, haddock, lobster, pollock, sea scallops, red hake, sea herring, wolf fish, and others, and during the warmer water months, the northern limit of some southern species, as black and red drum, cabio, and spot.

This offshore ocean fishery exists, as explained in subsection 21.04, entirely within the region influenced by river discharge. Much of the area surveyed by June and Reintjes (1957) is within the boundaries of the Delaware River estuary. It is for this reason that the fisheries off Delaware Bay represent an integral part of any economic evaluation of the Delaware River estuary. This is further demonstrated by the close relationship between the offshore fishery and the bay proper, as seen in the movement of migratory fishes into Delaware Bay for spawning and feeding. Indeed, the young of many species, such as the menhaden, begin their life within the bay and its tidemarsh streams. A comparison of Tables 3, 24, and 26 shows that several species of commercially harvested fishes occur on each list. These species, ranked in order of increasing commercial importance to the Atlantic coast fisheries (see McHugh, 1958) -- common eel, black drum, white perch, bluefish, weakfish, striped bass, croaker, and menhaden -- are found in the shore zone when young, and at later stages are harvested from the bay and are caught in the ocean fisheries.

The menhaden fishery is the largest in the region, producing over 622 million pounds, or 94 percent of the total catch in 1953, while

TABLE 26

A LIST OF THE FISHES AND SHELLFISH HARVESTED T[illegible]E OCEAN FISHERIES OFF DELAWARE BAY

(From June and Reintjes, 1957)

FISHES

Anglerfish
  Lophius piscatorius
Black drum
  Pogonias cromis
Bluefin tuna
  Thunnus thynnus
Bluefish
  Pomatomus saltatrix
Bonito
  Sarda sarda
Butterfish
  Poronotus triacanthus
Cabio
  Rachycentron canadus
Cod
  Gadus morhua
Common eel
  Anguilla rostrata
Conger eel
  Leptocephalus conger
Croaker
  Micropogon undulatus
Dolphin
  Coryphaena hippurus
Fluke
  Paralichthys dentatus
Grunt
  Haemulon species
Haddock
  Melanogrammus aeglefinus
King whiting
  Menticirrhus saxatilus
Little tuna
  Euthynnus alletteratus
Mackerel
  Scomber scombrus
Mackerel shark
  Isurus nasus
Menhaden
  Brevoortia tyrannus
Pollock
  Pollachius virens
Porgy
  Stenotomus chrysops
Red drum
  Sciaenops ocellata
Red hake
  Urophycis chuss
Sand perch
  Bairdiella chrysura
Sea bass
  Centropristes striatus
Sea herring
  Clupea harengus
Sea robin
  Prionotus species
Skates
  Raja species
Spot
  Leiostomus xanthurus
Striped bass
  Roccus saxatilus
Tautog
  Tautoga onitis
Tilefish
  Lopholatilus chameleonticeps
Trout (Weakfish)
  Cynoscion regalis
White hake
  Urophycis tenuis
White marlin
  Makaira albida
White perch
  Roccus (Morone) americana
Whiting
  Merluccius bilinearis
Windowpane
  Lophopsetta maculata
Wolf fish
  Anarhichus lupas

(Table continued on next page)

Table 26, Continued

<u>SHELLFISH</u>

Blue crab
Callinectes sapidus
Conchs
Busycon canaliculatum, and
Busycon carica
Lobster
Homarus americanus

Sea scallop
Placopecten magellanicus
Squid
Loligo pealei
Surf clam
Spisula solidissima

the otter trawl fishery for food fish amounted to nearly 21 million pounds, and the surf clam harvest was 7.7 million pounds of meats. Although sport fishing accounted for a small portion of the total landings, some 3 to 5 million pounds, it does contribute substantially to the economy of the area, particularly to recreational interest. An economic summary of these and the other fisheries of the area is given in Table 27.

TABLE 27

FLEET SIZE, REPLACEMENT VALUE,
NUMBER OF FISHERMEN EMPLOYED,
AND VALUE OF CATCH FOR 1953

From June & Reintjes (1957)

Fishery	Number of Vessels	Replacement Value of Vessels & Gear	Number of Fishermen Employed	Value of Catch
Menhaden	33	$6,300,000	957	$7,100,000
Otter trawl	86	2,850,000	285	2,000,000
Surf clam	46	920,000	130	963,000
Purse seine for Foodfish	3	200,000	24	150,000
Pot	20	200,000	40	190,000
Miscellaneous Commercial	20	100,000	40	200,000
Sport	250	1,675,000	500	900,000

The national economic inflationary trend and the improvement in gear is apparent in the menhaden fishery. While the replacement value of an average menhaden vessel and gear in 1953 (Table 27) was around $200,000, it is now $300,000. An electronically equipped steel-hulled vessel costs

about $500,000. The modern menhaden factory is a $4 million establishment, furnishing substances from which hundreds of products are made (Tressler and Lemon, 1951; Higgins, 1958).

Construction and operation of food processing plants are expensive. An oyster shucking house, equipped with mechanical means for moving oysters in and shells out and providing work for 50 to 60 shuckers, costs $25,000. To build a quick-freeze shellfish processing plant and a warehouse with a holding capacity of 300,000 pounds would require an investment of not less than $100,000.

Conservatively estimated, the commercial fisheries vessels, gear, and factories and the food processing plants of Delaware represent well over $15 million of investments.

It is obvious--when encompassing the combined value of the marine fishery resources, of charter boats and sport fishing business, of fishery vessels, of commercial nonfood-product factories and food processing plants--that Delaware River estuary-dependent activities represent a modest sum of over $60 million. This estimate is low because the fisheries harvest is not as high as it should be. We have already cited (page 21-47) the decline of just one fishery, the oyster industry, to about one-half of its former volume. A second example is even more striking. In former years there was an abundant shad fishery in the bay and river. Throughout the 19th century the annual shad catch weighed between 10 and 19 million pounds. Shortly after the turn of the century there was a precipitous drop in the fishery and after 1920 the catch has rarely exceeded 500,000 pounds according to various statistical publications of the United States Government. Pollution control and abatement is required before the shad populations of former years can be expected to survive the upstream spawning migration and the downstream run of the young shad to the estuary and open ocean. Large numbers of young shad, 4 to 6 inches in length, are now common along the shores in the upper portion of the estuary (compare with Table 3, page 21-20). We could witness a noticeable return of the shad within a few years, if pollution abatement and control continues.

Fish kills in the lower Delaware River are a yearly occurrence, generally in early June, and although there has not been a study made of the cause or causes, the lack of oxygen or the presence of toxic substances are suspected. Data on oxygen-lack within the lower River has been amply supplied by Cronin (1954a) and discussed by Dr. A. Joel Kaplovsky in Section XIX, page 19-8. The causes of this lack can be due to a single factor or a complex of physical, chemical or biological phenomena; further studies are required to solve the annually recurring fish kills.

21.09 CONCLUDING REMARKS

Statewide interest in marine biology and a recognition of the value of the aquatic resources of Delaware led to the inception of a marine science program at the University of Delaware in 1951. This program, of education and conservation advisement based upon research findings, has been aided further by grants from federal, state, and private sources. The central research interest of this program is the Delaware River estuary: the

environment, the organisms, the inter-relationship between environment and organisms, and the production of renewable harvestable resources.

This scientific investigation of the Delaware River estuary has provided intellectual enrichment, exciting experiences and self-rewarding achievement for our researchers. Our growing understanding of the estuary and its resources has contributed to intrastate programs and has enabled representatives of the State of Delaware to better participate in matters of interstate concern, as on the Interstate Commission on the Delaware River, the Atlantic States Marine Fisheries Commission, and the Water Resources Association. The marine program, no less than any other academic pursuit, has furnished cultural and recreational as well as practical advantages to the people of Delaware. We extend these advantages to all who wish to learn and to share with us our increasing knowledge about the Delaware River estuary--its wonderful world of life, its bountiful harvests, and its present and potential value to the rapidly developing industrialized coastal area.

We commend to your attention, as a rewarding intellectual experience, the fruits of learning being produced by the newly developing field of estuarine research. If, however, you are concerned only about an economic evaluation of the river basin we urge you to look at the entire fresh water-affected and dependent area and to make a full appraisal of the present and potential role of the DelawareRRiver estuary in the overall economy of the river basin. Three publications can be cited as particularly suited for the purpose of obtaining the perspective necessary for this appraisal. It is of interest to note that these publications are reports from separate symposia and committee undertakings resulting from the combined efforts of many specialists.

The first, a book that all persons engaged in resources research and in administration of the public welfare should consult, resulted from a desire of anthropologists "to keep abreast of all the means at man's disposal to affect deliberately or unconsciously the course of his own evolution; in this case, what man has done, and is doing, to change his physical-biological environment on the earth." This volume, <u>Man's Role in Changing the Face of the Earth</u>, edited by Thomas (1956), resulted from an international symposium held to consider in retrospect, process, and prospect three interrelated factors: (1) the earth's resources, (2) the numerical pressure of population upon, and sustained by, the resources, and (3) man's differing cultures, or ways of life. Thomas writes (1956), "Within the last century man has developed the idea that change is continuous and includes himself. Conceptions of fossil man (prior to present man), of biological evolution (in which man is included with all other living phenomena), and of the vast duration of earth history are but a few examples of ideas developed by science and become part of the public consciousness since the mid-nineteenth century. Can the uniqueness of the present be made clearer for those within it by focusing on the role of man in altering the earth's surface, keeping in mind the longevity of the period in which he has been doing so? This Symposium is intended to contribute to such an understanding."

From the start of the "Treatise on Marine Ecology and Paleoecology" was planned as "...an appraisal of accomplishments in the fields of marine ecology and paleoecology, particularly those ecological investigations related directly or indirectly to paleontology." Volume one of the Treatise, "Ecology," edited by Hedgpeth (1957), contains a wealth of information that is applicable to estuarine ecology. Among the many topics discussed by specialists are: concepts of marine ecology; solar radiation, submarine daylight, and photosynthesis; salinity; temperature; oxygen in the ocean; nutrient elements; organic detritus; interrelations of organisms; plankton; bottom communities; and estuaries and lagoons.

The "Proceedings, Salt Marsh Conference, 1958," edited by Ragotzkie (1959), resulted from geologists, hydrographers, botanists, and zoologists meeting for a common purpose, to learn what the others had and might contribute to the study of salt marshes. The major categories of topics included in the conference were the land structure, vegetation, and ecology of salt marshes and historical records obtainable from salt marshes.

It has been the purpose of the author of this section to outline what is known about the boundaries of the Delaware River estuary, some of the man-caused changes that affect the environment of estuarine organisms and the productivity of the estuary. This estuary is the tidal portion of the Delaware River basin, including the tidal marshes along its shores and a vast area of over 3,000 square miles off its mouth. Man-caused changes in river flow, although influential in the distribution of estuarine organisms, are not as damaging as pollutants. Both changes, river flow and pollutants, are engineering problems that must be better solved than they are today if biological productivity of the estuary is to remain high or to be improved.

We should be ever critical of manmade changes of naturally occurring factors affecting the estuary, particularly of the river flow characteristics, until it can be demonstrated that these will not be detrimental to estuarine life, especially to commercially valuable species. For example, the ability of aquatic organisms to conserve water in their tissues under varying salinity and associated environmental conditions is what determines where those organisms can exist within the estuary. Variations in the fresh-water flow that bring about changes in the pattern of water circulation of the upper estuary can markedly affect the distribution of planktonic species and those bottom-dwelling species, such as the oyster, that spend their larval stages carried by the currents.

In addition to the "old-fashioned" type of soil, sewage, and industrial pollutants, a new, more deadly series--detergents, insecticides, and radioactive substances--poises an even more critical problem than does fluctuation in the fresh-water flow. Essentially, the challenge is to achieve better management of our natural resources to counteract a century of decrease due largely to inadequate solution of pollution problems.

The fresh-water flow from the Delaware River basin and all its contained minerals, nutrients, and pollutants, has an effect upon some 4,000 square miles of coastal waters bordering the states of New Jersey, Delaware, and Maryland. The value of marine resources harvested yearly from this area

added to the investment in vessels, equipment, and factories processing the harvest, is in excess of $60 million. To this can be added another type of resource, seawater, which includes extraction of metals from sea-water, as at the Northwest Magnesite Company plant at Cape May, New Jersey, and the probable future source of large volumes of fresh water from the sea. Utilization and management of these mineral and water resources, the food and commercial products crops, and the recreational aspects of the natural resources constitute an expanding frontier of man's activities.

Tidal marshes have been found to be highly productive of estuarine life, particularly plants, and they contribute much to estuaries. We have learned from Dr. Jay L. Harmic (Section XX, Exhibit F on page 20-28, and Exhibit G on page 20-29) that Delaware marshes are essential to the production and maintenance of waterfowl and fur bearer populations. These marshes, particularly tidal ones, are valuable also to the fisheries of the Delaware River estuary. Indeed, if all tidal marshes were lost from the productivity of the estuary, our fisheries harvests might well drop to less than half of their present volume. A positive program of marsh utilization must be adopted so that industry, agriculture, and recreation (elimination of mosquitoes), can coexist with fisheries. Impoundment and flooding of marshes for the dual purpose of mosquito control and waterfowl and/or fur bearer management are contrary to the best interests of fisheries. A suitable number of tidal marshes must be managed for maximum benefit to the fisheries(see Exhibit I on page 20-31). We concur with Dr. Harmic that the Little Creek area is, if a marsh must be lost from estuarine production as a dredge spoil disposal area, a good choice on the basis of our present knowledge.

Our report upon the biological productivity of the Delaware River estuary provides sufficient information on its value to appeal to every conservation-thinking citizen of the United States. Wanton destruction of renewable natural resources, instead of seeking opportunities of increasing this production afforded by our accumulating scientific and engineering abilities, is not only a crime today, but it is vital to future generations that mankind better utilize our rapidly diminishing per capita natural resources. This consideration is obviously stimulated by ominous forecasts of what lies ahead for worldwide increasing populations, as reported, for instance, in a recent issue of Newsweek (April 27, 1959) on "The avalanche of babies." Locally, as applies to this report, the problem is to provide for our future generations by developing the ability to engineer changes that will have a beneficial effect upon the biological productivity of the Delaware River estuary. This difficult problem may be solved by future generations in their search for living space, food to eat, and water to drink. Although each of these three basic requirements for life seemingly exist today in plentiful supply, it is not too soon to recognize the probability of their decreasing abundance and to provide the proper background of information by initiating research upon the feasibility of manipulating estuarine productivity as a part of the overall consideration of our water resources.

a. Summary. In dealing with the economic value of the Delaware River estuary, we are concerned with an area some 4,000 square miles in extent which directly affects the economy of the coastal portion of New

Jersey, Delaware, and Maryland. This coastal water area is responsible for a large fisheries harvest, for minerals, and for recreational uses valued at several millions of dollars with an annual ultimate value to the consumer probably measurable only by hundreds of millions of dollars. The capital investment to provide this annual economic benefit from estuarine resources is obviously of great magnitude. The fact that Nature furnishes the initial portion of the capital does not give mankind the right to misuse or squander it.

21.10 APPENDIX TO SUBSECTION 21.05 ON TIDEMARSH PRODUCTIVITY

a. Hypothesis on tidemarsh productivity. Although the broad pattern of events outlined in the following hypothesis is substantiated by data, certain of the statements may be modified as data accumulates. It is for this reason that the topics on which future research should be undertaken are underlined. Figure 13 graphically supplements Kalber's (1959) hypothesis.

(1) The bulk of nitrogen and phosphorus in the river runoff is probably inorganic.

(2) Both inorganic and organic levels of phosphorus and nitrogen are built up in the lower river area.

(3) Presumably, due to high BOD (Biological Oxygen Demand) and a narrow light-penetration zone, inorganic nutrients entering the "nutrient buildup" area are not bound there by autotrophic activity and thereby largely lost to the estuary at this point.

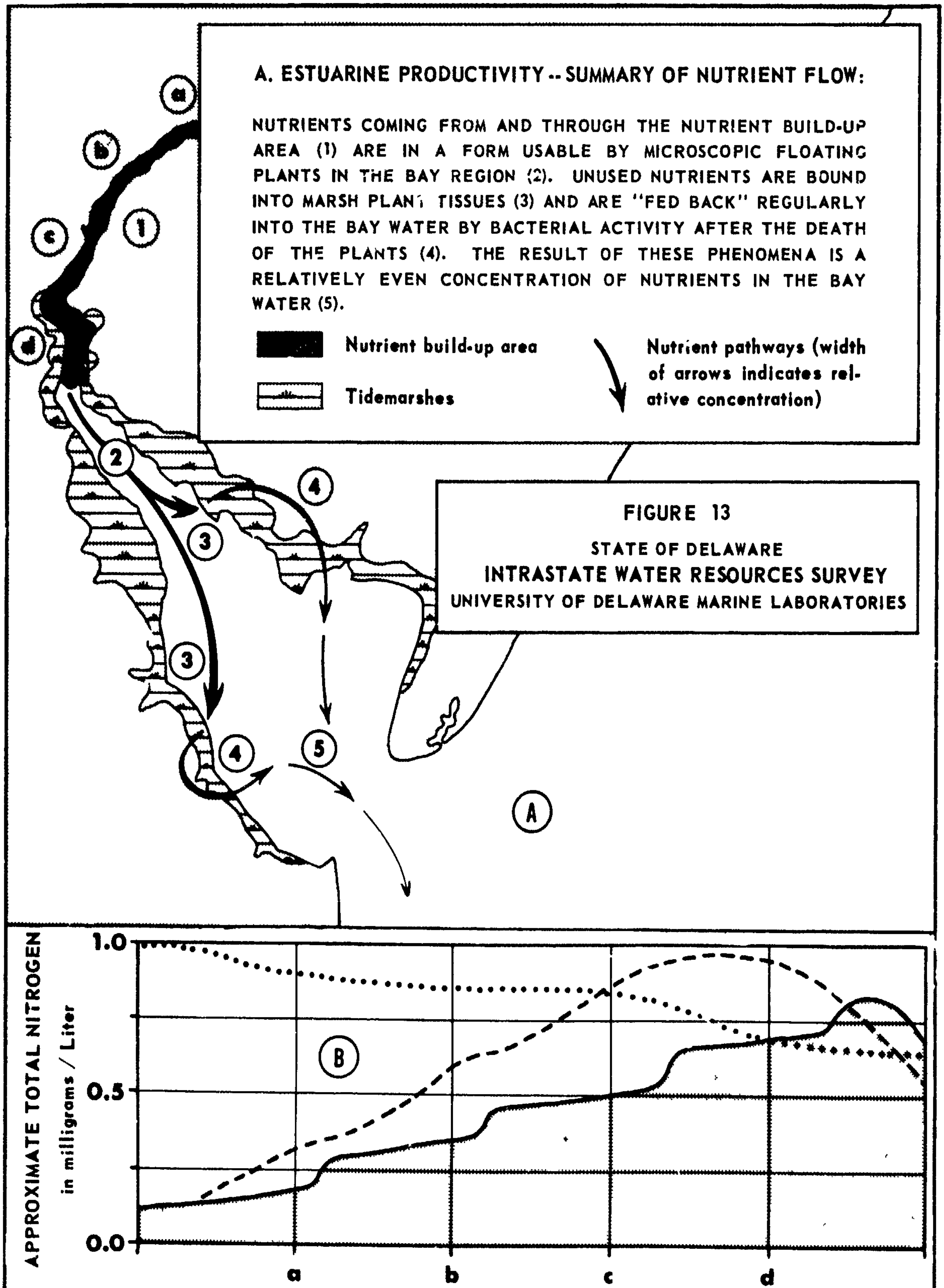
(4) Much of the added organic material is broken down under anaerobic conditions in the downstream end of the "buildup" area. Inorganic phosphorus and nitrogen are not bound here because of anaerobic and other conditions.

(5) Reaeration at the extreme downstream end of the "buildup" area is apparently rapid, allowing a sudden utilization of inorganic nutrients. The same general phenomenon may occur in the rest of the bay, probably in the sediments. Some of the inorganic substances are passed directly to the marshes for regenerative breakdown.

(6) Due to the shallowness of the bay, mixing is apparently good at all seasons. Mixing allows regenerated inorganic nutrients to be brought to the surface, but a narrow light penetration zone prevents rapid depletion by phytoplankton.

(7) Inorganics released from the bottom, but not utilized in the photic zone, are brought to the marshes for binding in rooted aquatics.

(8) Inorganics are made available again through: (a) regeneration in marshes from free organics; (b) breakdown in marshes from rooted aquatics.



B. THESE CURVES SHOW THE TREND IN AMOUNT OF NUTRIENTS IN THE DELAWARE RIVER AT LOCATIONS a, b, c, AND d IN RELATION TO BIOLOGICAL OXYGEN DEMAND (-----) AND LIGHT PENETRATION. TOTAL NITROGEN (——) INCREASES STEP-WISE DOWNSTREAM AND TOTAL PHOSPHORUS (NOT SHOWN) PROBABLY HAS A LESS PRONOUNCED, BUT SIMILAR BUILD-UP. IF LIGHT PENETRATION INTO THE RIVER WATER WERE GREATER, THE AMOUNT OF THESE NUTRIENTS WOULD DECREASE DOWNSTREAM (·····).

(9) These ordinarily limiting inorganics (phosphate and nitrate) are, therefore, steadily fed out into the bay in a form available to organisms. A productive "steady state" in nutrient stores thus would be maintained, instead of alternate periods of "feast and famine."

b. Summary. Two major concepts are introduced by this hypothesis:

(1) A "nutrient buildup" area prevents loss of upstream nutrient contribution, and contributes substrates from which nutrients can be obtained.

(2) The fate of the nutrients can be characterized by the large proportion of organic breakdown that occurs in the bay, and by the uptake of these nutrients by the marshes, where they are "stored" in rooted aquatics and fed back at relatively even rates through the seasonal decomposition of the plants.

The result of these phenomena is relatively even concentration of nutrients in the bay water.

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SECTION XXII

STATE HIGHWAY DEPARTMENT
BEACH AREAS AS FUTURE POPULATION GENERATORS

22.01 INTRODUCTION AND SUMMARY

In order to predict the effects of the beaches of Delaware on the growth of population for the years 2010 and 2060, it is necessary to apply proportions developed from existing conditions. Today 90 percent of the beach population prefer the Atlantic coastline of Delaware with the remaining 10 percent preferring the Delaware Bay coastline. From the existing desirability of the Delaware Bay beaches, it is estimated that in the future 6 percent of the total beach population will be concentrated in the area from Lewes Beach to Broadkill Beach, with the remaining 4 percent being scattered northward towards Kitts Hummock.

a. Locations. Along the Atlantic Coast of Delaware there exists 126,700 feet of beach front, of which 76,000 feet is owned by the State, 14,300 feet is owned by the Federal Government, and the remaining 36,400 feet is owned by private interests. On the Delaware Bay beach front the public owns 25,840 feet of beach front from Lewes Beach to south of Broadkill Beach. All other bay-front lands, with a few minor exceptions, are privately owned. On the basis of the desirability of the beaches and the existing ownership of the beaches, it is considered that in the future the majority of daily beach users will be concentrated along the Bay from Broadkill through Lewes and along the entire Atlantic coastline. The remaining Bay regions, ... which only 4 percent of the total beach population is expected to use, will be primarily made up of fishing resorts.

b. Potential. Along the Atlantic Coast it is estimated that the State beach front can provide for 228,000 persons each day, while the State park lands, which lie behind the beach front, can adequately support an additional 116,000 persons each day. Therefore, the State-owned lands along the Atlantic Coast are capable of providing for 344,000 persons in a single day. In addition, the Federal Government owns 14,300 feet of beach front and approximately 1,200 acres which should adequately support an additional 91,000 persons if developed into a state park. The remaining 36,400 feet of beach front belonging to private interests is capable of supporting an additional 109,000 persons each day. The sum of these ownerships, both public and private, have an area which, if properly developed, can support approximately 544,000 beach users each day.

c. Predicted usage of beach areas. It is estimated that in the year 2010 a total of 3,914,000 persons will visit the beaches of the State of Delaware; a maximum of 183,300 persons will visit those beaches in a single day; 13,300 persons will live in the beach areas the year around; and 76,400 will live in the area during the summer, requiring 15,000 homes. It is estimated that the area to be covered by the homes and businesses will expand from the present approximately 1,000 acres along the Atlantic Coast to 3,750 acres in the year 2010.

In the year 2060 it is estimated that 9,025,000 persons will visit Delaware in a season, of which 423,000 will visit those beaches in a single day. The permanent population of the beach areas will be 30,700 and the summer population will be 207,000, requiring 34,500 homes covering an area of approximately 8,600 acres.

d. Summary. Therefore, by the year 2060, if the beaches and adjacent areas are properly planned, the lands belonging to the State and Federal Government will be capable of supporting most of the daily beach users. With the private beaches included, the daily beach users should have sufficient area for recreational purposes. However, as the number of summer homes increases, it will become necessary to move developments inland and away from the beaches a distance in excess of 3 miles. Although there are no records to support this conclusion, it is assumed that these summer homes, in preference to being a mile or more from the beach, will be constructed in developments around the perimeter of Rehoboth Bay, Indian River Bay, and Assawoman Bay.

e. Recommendation. On the basis of the above summary, it does not appear that the purchase of additional beach lands by the State would be wise, with the exception of obtaining the Federally-owned lands at Fort Miles. However, it is paramount that the State should begin to prepare and develop a well-organized state park along the beaches on a 100-year plan.

22.02 PREPARATION OF ESTIMATES

a. Population estimates. In order to predict the beach population in the year 2010 and in the year 2060, it was necessary to develop population estimates of the Wilmington Metropolitan Area, Southern Delaware, the remaining Southern Basin and Coastal Area, the Eastern Shore of Maryland, the Baltimore and Washington area, and the Philadelphia Metropolitan Area. To do this, the data on the predicted population growths to 2010 provided by the Office of Business Economics was used. Figure 1 (page 20-3) shows the plotted results of that data. However, it was necessary to use some method of extrapolating the data in order to predict the populations in 2060. After comparing the results which could be obtained by using an arithmetic rate of increase and by using a percentage rate of increase, it was found that both methods gave similar results for heavily-populated regions such as the Philadelphia Metropolitan Area. However, for the rapidly growing regions such as the Wilmington Metropolitan Area the percentage increase provided higher results; consequently this technique was used as it produced what seems to be more reliable estimates for regions having room to expand as well as satisfactory results for regions of present high population density.

The plotted results shown in Figure 1 produced very similar rates of growth for the Wilmington Metropolitan Area and for the Southern Basin and Coastal Area. Consequently, the average of these two rates of growth was taken to be representative of the State of Delaware and the Eastern Shore of Maryland. In order to predict the population growth for the Baltimore-Washington area, the rate of growth typical of the Philadelphia Metropolitan Area was applied. Consequently, the final results obtained in estimating the population growth of the regions which contribute to the beaches of Delaware are shown in Table 22-1.

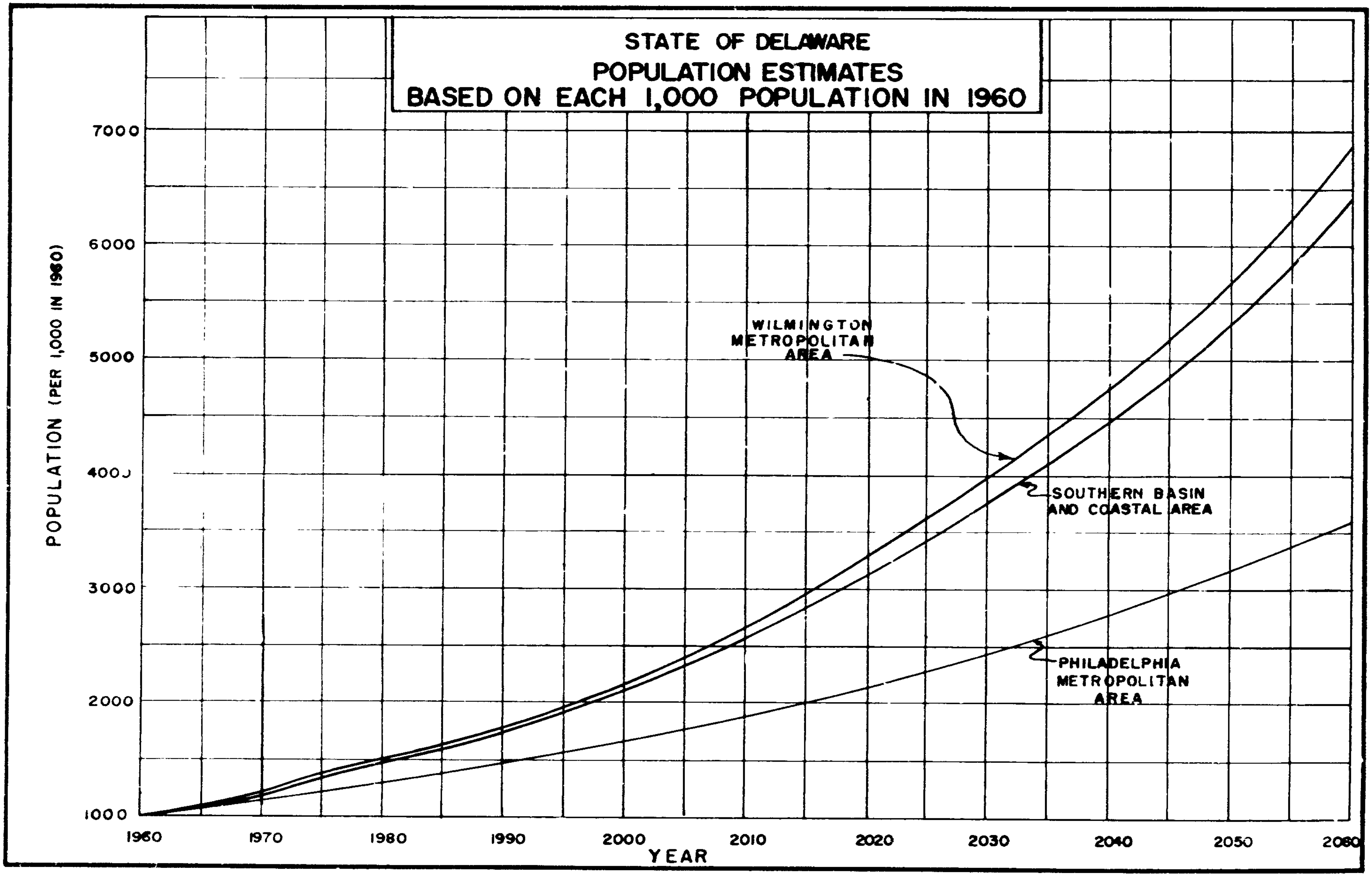
STATE OF DELAWARE
POPULATION ESTIMATES
BASED ON EACH 1,000 POPULATION IN 1960
WILMINGTON METROPOLITAN AREA
SOUTHERN BASIN AND COASTAL AREA
PHILADELPHIA METROPOLITAN AREA
POPULATION (PER 1,000 IN 1960)
YEAR
1000
2000
3000
4000
5000
6000
7000
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060

TABLE 22-1

ESTIMATED POPULATIONS OF CONTRIBUTING AREAS

Region	2010	2060
Wilmington Metropolitan Area	1,000,000	2,600,000
Southern Delaware	514,000	1,104,000
Southern New Jersey	785,000	2,206,000
Baltimore-Washington	4,770,000	10,000,000
Eastern Shore of Maryland	234,000	597,000
Philadelphia Metropolitan Area		

b. Beach population estimates. The technique used in estimating the number of people who will use the beaches of Delaware from the contributing regions discussed in section 22.02, a., is that presented by the U. S. Army Corps of Engineers in their report entitled "Beach Erosion Control Report on Cooperative Studies of Delaware Coast--Kitts Hummock to Fenwick Island," dated May 1, 1956. In this report the U.S. Army Corps of Engineers estimated the number of people who visited the beaches of Delaware in 1950. They developed an estimated contributing population of which 5 percent represents the average maximum daily population to visit the beaches 20 times in a season. One-third of this figure is expected to visit the beaches 40 times in a season. Their estimate of a contributing population is 100 percent of the population of the State of Delaware and 15 percent of the populations of the Eastern Shore of Maryland and the Baltimore-Washington areas. However, from observation and expected improvement of north-south transportation routes, this investigator has added 2 percent of the Philadelphia Metropolitan Area, 2 percent of the Southern New Jersey area, and 100 percent of Salem County, which will make up part of the Wilmington Metropolitan Area. In addition, this investigator predicts a maximum population for a single day which might be expected during a holiday week-end by increasing the 20-day maximum average by 50 percent.

TABLE 22-2

PREDICTED BEACH USER POPULATION

Region	Percent Contributing	Contributing Population 2010	Contributing Population 2060
Wilmington Metropolitan Area	100	1,000,000	2,600,000
Southern Delaware	100	514,000	1,104,000
Southern New Jersey	2	16,000	44,000
Baltimore-Washington	15	716,000	1,500.000
Eastern Shore of Maryland	15	35,000	90,000
Philadelphia Metropolitan Area	2	164,000	303,000
Totals		2,446,000	5,641,000
Average Peak Day Population		122,300	282,000
Maximum Peak Day Population		183,300	423,000
Total Season Population		3,914,000	9,026,000

c. Estimate of permanent and summer populations. Since it is considered that the majority of development will occur in the regions along the Atlantic Coast, a guide using Rehoboth as a standard was developed. Rehoboth represents the single example of what might be expected to occur on the privately-owned lands along the Atlantic Coast in the next 50 years. Consequently, for lack of better information, it must be used to represent future development.

The permanent population of Rehoboth today (1958) is 2,350 with an increase to 13,500 in the summer. In addition, an estimated 700,000 persons visit Rehoboth Beach each summer. Therefore, the permanent population represents 17.4 percent of the summer population and 0.34 percent of the total number of beach visitors. This does not intend to indicate that the permanent residents use the beaches only 0.34 percent of the time; it merely expresses the permanent and summer populations as percentages of the previously-predicted daily beach population. From a count of the residences in the Rehoboth area from an aerial photograph, it is estimated that an approximate figure of 6 persons per home is adequate. In addition, as an area grows, developing businesses, streets, and other related users of land areas, an estimate of 4 homes per acre is reasonable.

TABLE 22-3

ESTIMATE OF SUMMER AND PERMANENT POPULATION

	2010	2060
Summer Resident Population	76,400	176,400
Permanent Resident Population	13,300	30,700
Total Season Population	89,700	207,100
Number of Homes	15,000	34,500
Residence Land Requirements (Acres)	3,750	8,600

d. Estimate of land area needs. According to the National Park Service of the U.S. Department of Interior, a minimum of 50 square feet of beach is needed for each person using the beach area, and a minimum of 25 acres is needed for each 1,000 persons using the park area.

At present the State of Delaware owns 76,000 feet of beach front along the Atlantic Coast and approximately 2,900 acres. Since the beach front averages 150 feet in width, these beaches will support 228,000 people in a given day. The 2,900 acres, if properly developed into a state park, will support an additional 116,000 persons each day. This totals 344,000 persons who can be supported by State-owned lands along the Atlantic Coast in a single day.

The Federal Government owns 14,300 feet of beach front and 1,200 acres. On the basis of a beach width of 150 feet, these Federal lands can provide recreation for 43,000 persons along the beaches and 48,000 persons in a developed park area, totaling 91,000 persons who may be accommodated in a single day. The combined total of Federal and State lands, if properly developed, will support 435,000 persons.

In private ownership their remain 36,400 feet of beach front capable of supporting 109,000 beach users in a single day.

As noted in section 22.02, c., 3,750 acres will be needed in the year 2010 and 8,600 acres will be needed in the year 2060 for homes and other buildings., of which 96 percent will be near the Atlantic Coast. If the existing private lands along the Atlantic Coast were developed, it would require some homes to be placed as far as 3 miles from the beach. Since summer residents would object to this as an undesirable location for their summer homes, it is obvious to this investigator that as high as 5,000 acres of land will be developed around Rehoboth Bay, Indian River Bay, Assawoman Bay, and along the Delaware Bay between Broadkill and Lewes.

22.03 CONCLUSIONS

It is concluded that the influence of the beach areas on permanent populations is not of major consideration in the prediction of population growths in Sussex and Kent Counties. However, the influence of the beaches on a seasonal population growth is of prime importance. During the summer, a relatively dry season, water will be needed in the year 2010 to support a population of 89,700 persons on a 24-hour basis and 183,300 persons on a 4- to 8-hour basis. In the year 2060 this figure will be 207,-100 on a 24-hour basis and 423,000 on a 4- to 8-hour basis. In 2010, if it is assumed that the summer residents will use water at the rate of 125 gallons per person and the daily visitors will use water at the rate of 25 gallons per person, the maximum daily water needs will be 15.8 million gallons, the 20-day maximum average water needs will be 14.4 million gallons, and the average day water needs will be 12.2 million gallons.

If proper usage is made of the existing State and Federal lands and if the private beach fronts remain open to public use, there will be sufficient land for bathing and other recreational purposes to support the expected beach population for the year 2060. However, the condition will be approaching a saturation point, pointing out the important need for proper development and planning to begin today, not in the year 2060. It is further concluded that great developments of summer homes will mushroom around the water fronts of Rehoboth, Indian River, and Assawoman Bays. It is further suggested that as the work week becomes shorter, the retirement age becomes younger, and man's life span increases, the number of summer homes in the years 2010 and 2060 will far exceed those presently predicted.

SECTION XXIII

STATUS OF SALT WATER BARRIER EVALUATION

23.01 GENERAL

In the course of the water resources survey there has been much discussion with regard to the feasibility of a salt water barrier in the lower Delaware River Basin. Many of the comments and opinions regarding this controversial subject were directed at the effect of such a structure upon the present, with less attention to future needs which might be resolved by the construction of a barrier. The request for an evaluation of a salt water barrier was initiated to inquire into its practicability as a possible means of meeting projected water needs in the lower Delaware, with its associated benefits, and thereby becoming part of an overall water development plan for the Delaware River Basin.

23.02 EARLIER BARRIER PROPOSAL

The salt water barrier concept did not originate in the State of Delaware. Salt water barriers already exist in various locations throughout the world. The State of California has made an extensive barrier study in the San Francisco area[1]. Further, Mr. E. H. Aldrich[2] proposed such an undertaking within the Delaware River Basin in a paper read before the Pennsylvania Water Works meeting on October 12, 1955.

Mr. Aldrich proposed the barrier as an alternate development to the Incodel and/or Pennsylvania plans for water development in the Delaware Valley. The barrier proponent stated, "In this alternate development (salt water barrier) there seem to be possible solutions to many of the difficult problems involved in the development of the Delaware River Valley and, in particular, in the development of the water resources of the lower basin. This is the part of greater interest to lower Pennsylvania and New Jersey and to the State of Delaware."

"... It will, it is believed, provide the maximum benefits to the largest number of people and industry, without permanent harm to any, with an outlay of money which seems almost fantastically low in comparison with the combined costs of equal remedial projects which have heretofore been presented."

Mr. Aldrich proposed the construction of a tidal dam to separate completely the fresh water from the salt water in the lower estuary of the Delaware River. He suggested that the elevation of the top of the dam be at or about the average maximum water elevation resulting from tidal variation. Two locations were suggested: one above the entrance of the Chesapeake and Delaware Canal, which would require works approximately 5,000 feet long, and the second is just below the Chesapeake and Delaware Canal at or near Reedy Island. The latter location would require a dam some 10,000 feet long. Further clarification was offered with the following statements:

"Damages and disruptions which now occasionally occur throughout the tidal area from high water in excess of normal high tides, caused by flood tides or wind action, will, by the nature of the proposed construction, be reduced since the flowage area over the top of the dam, coupled with the time limits of high tidal action will not permit a large flow into the basin. By proper gate manipulation and release of stored water on low tide such overflow can effectively be controlled."

. . . .

"... Suffice it to say that the tremendous industrial development now taking place throughout the lower valley and particularly in the section between Philadelphia, Camden, and Trenton, would not and could not have taken place without feeling the assurance that the navigation facilities of the lower valley area would be maintained and improved so far as feasibly necessary and possible."

It should be noted that a barrier structure would sustain controlled elevation, and Mr. Aldrich continues, "... It must be further remembered that there are periods of low tides during which the water elevations up and down the estuary range from 3 to 5 feet below mean low water.

"It seems evident that if the water level is maintained 6 to 7 feet above mean low water by a barrier dam, such as is herein proposed, and from 9 to 12 feet above occasional low water periods, the navigation throughout the estuary will be materially improved, not only in the main channel, but outside the channel and in all the slips, anchorages and river branches throughout the area. ..."

. . . .

Mr. Aldrich further commented, "Not only will the higher level be beneficial and saving in dredging costs, but the elimination of the variable level of the water produced by tidal action will result in easier and better navigation, reduce sand bar formation and eliminate the very bothersome effect of ebb and flow tidal currents.

"The one, and, it is believed the only, important disadvantage to the installation of the barrier dam is that navigation locks must be provided to enter the estuary when differences in water level prevail. It is recognized that some delay in shipping will be occasioned by the necessity to pass through locks. Probably it may be argued that more careful navigation is required to pass through such locks, particularly during periods of fog or storm. As a factor which may more than offset delay and increased navigation difficulties caused by locks, occasional periods of anchorage or dockage in fresh water tend to remove ship bottom encrustations and thereby increase ship travel speed.

"It is believed that factors in the proposed plan which are objectionable are not material and that the otherwise enormous advantages to be gained by a fresh water estuary far outweigh the minor disadvantages and inconveniences resulting from navigational locks."

23.03 RECOMMENDED BARRIER FEASIBILITY STUDY

Brig. General Norman C. Lack, (USA. Ret.), Delaware's representative on the Delaware River Basin Advisory Committee, has been for several years a proponent of studying the feasibility of the barrier dam. Through the continuous efforts of General Lack, in which many of the potential advantages were cited, action was started to hold a barrier hearing for the express purpose of investigating the practicability of such an undertaking. The following resolution was adopted by the Committee on Public Works of the U.S. Senate on April 28, 1958.

"Resolved by the Committee on Public Works of the United States Senate, that the Board of Engineers for Rivers and Harbors, created under Section 3 of the Rivers and Harbors Act, approved June 13, 1902, be, and is hereby requested to review the reports of the Chief of Engineers on the Delaware River, New York, New Jersey, and Pennsylvania contained in House Document numbered 179, Seventy-third Congress, Second Session, and other reports, in conjunction with a view to determining the feasibility of construction of a barrier in the Delaware estuary, such study to consider the economic and physical effects of such a structure, the costs and potential benefits of the structure, and the economic and physical relationship of such a structure to other works of improvement now being planned for the Delaware River Basin."

23.04 BARRIER HEARING

In accordance with the resolution adopted by the Committee on Public Works, the Corps of Engineers was directed to take appropriate action which entailed, initially, the holding of a public hearing. The Public Hearing announcement distributed is shown below.

U. S. ARMY ENGINEER DISTRICT, PHILADELPHIA
CORPS OF ENGINEERS
2635 Abbottsford Avenue
Philadelphia, Penna.

NAPGW

20 August 1958

NOTICE OF PUBLIC HEARING ON DELAWARE RIVER

BARRIER DAM IN THE ESTUARY

The District Engineer has been directed to make a survey and submit a report on Delaware River, New York, New Jersey, Pennsylvania and Delaware pursuant to the following resolution adopted by the Committee on Public Works of the United States Senate:

(The resolution was presented in Section 23.03 above, and is not repeated here.)

In order that the required report may fully cover the matter, a public hearing will be held in Nemours Auditorium, Nemours Building, 11th and Orange Streets, Wilmington, Delaware at 10:30 A. M. on 20 October 1958.

All interested parties are invited to be present or represented at the above time and place including representatives of Federal, State, County and municipal agencies, and those of commercial, industrial, civic, highway, railroad and waterway transportation interests, and property owners concerned. They will be afforded full opportunity to express their views concerning the character and extent of the improvement desired and the need and advisability of its execution.

The proponent of the barrier, the State of Delaware, suggest a site in the New Castle - Pea Patch Island locality. The primary purpose of such a structure would be to prevent the intrusion of salt water into the area upstream of the barrier. The barrier would create a slack fresh water pool at the elevation of the present mean high tide extending from the structures to the head of tide at Trenton, N.J. on the main stem of Delaware River and upstream on the tributary streams above the barrier to the head of tide on these streams. All communities above and below the barrier in the tidal section of Delaware River and its tributaries would be affected.

The proponents of the barrier anticipate vast benefits to industries requiring fresh water. They also envision the expansion of present industries and the development of new industries as a result of the fresh water supply.

For your information, the existing project for the Delaware River between Philadelphia and the Sea provides for a channel 40 feet deep and 800 to 1000 feet wide. In 1956, the District Engineer held a public hearing in Philadelphia in response to a Congressional Resolution calling for a review of this project. Local interests stated at that hearing their desire that the existing project between Philadelphia and the Sea be modified to provide for a channel 50 feet deep and 1000 to 1200 feet wide. A privately constructed channel 40 feet deep and 400 feet wide extends from Reedy Point to Delaware City, and it is understood that local interests desire that this channel be extended upstream to rejoin the main ship channel in the vicinity of New Castle. These existing and proposed improvements in navigation channels will be affected by the proposed salt water barrier.

Sponsors are urged to present pertinent factual material bearing upon the general plan of improvement desired, and the economic justification of the undertaking. Specific information is desired concerning the following:

a. Location of barrier and normal elevation of pool to be impounded;

b. Height of non-overflow sections of barrier;

c. Desirability of highway crossing the structure;

d. Dimensions and number of locks to pass shipping in the main channel and the channel in Hamburg Cove;

e. Effect on navigation;

f. Effect on salinity and other pollutants;

g. Benefits resulting from reduction of salinity above the barrier, to include comparisons with problems and costs of developing alternate water sources of equivalent quality;

h. Extent of local cooperation that would be provided.

Opposing interests, if any, are urged to state the reasons for their position. Specific information on the following is requested in the event such persons consider the adverse effects are possible:

a. Fish and wildlife values, to include oysters;

b. Effect on navigation, present and prospective, to include discussions of delays and sizes and number of locks necessary to minimize delay;

c. Effect on waterfront properties;

d. Effect on existing drainage systems;

e. Effect on existing sewer and waste outfalls;

f. Flood heights above and below the barrier.

Oral statements will be heard, but for accuracy of record all important facts and agreements should be submitted in writing, in quadruplicate, if possible, as the records of the hearing will be forwarded for consideration by the Secretary of the Army. Written statements may be handed to the undersigned at the hearing or mailed to him beforehand.

Please bring the foregoing to the attention of persons known to you to be interested in the matter.

(Signed) W. F. Powers)
W. F. POWERS
Colonel, CE
District Engineer

A public hearing on the matter of the feasibility of constructing a barrier dam in the Delaware estuary, pursuant to the notice of the public hearing issued August 20, 1958, was held by the U.S. Army District, Philadelphia Corps of Engineers, at Wilmington, Delaware, as specified. Colonel William F. Powers, U.S. Army Engineer District, Philadelphia, presided. A summary of the presentations and comments presented at this hearing is a matter of record[3].

It was pertinent for the position of the State of Delaware that representatives, expert in the various fields which may be affected by such an undertaking, make statements for the record. For the sake of brevity, the statements of Governor Boggs, members of the Coordinating Committee (Mr. R. A. Haber and Dr. A. Joel Kaplovsky) and a summary statement made by General N. C. Lack are contained herein.

(At this point Colonel Powers introduced Gov. Boggs to the session.)

GOVERNOR BOGGS: Thank you, Colonel Powers. Ladies and gentlemen, on behalf of the State of Delaware, I would like to extend a very sincere welcome to you, Colonel Powers and your staff.

COLONEL POWERS: Thank you, sir.

GOVERNOR BOGGS: And I also wish to welcome all of you distinguished folks who are here today from other states and other parts of the country having an interest in this subject, the subject of this hearing, either pro or con.

As you know, Delaware is becoming ever-increasingly cognizant of the seriousness of its future fresh water situation. In December of 1954, I appointed a Water Resources Study Group in this State. This Committee prepared a report which can be made a part of this hearing. . fully realize the necessity of planning today for the fresh water to be used by our citizens of tomorrow.

The Corps is aware that our physical terrain presents problems for impoundment; that our saline borders endanger the recharge of our under ground sources; that our State streams have little potential value as fresh water suppliers. It would, therefore, seem that our very future existence necessitates a dependable and visible source of proper quality water from beyond our borders or from the Delaware River. This is why we are vitally interested in a study of a barrier. To us, it is a question of security, weighed by economy and practicability; a question of miles of aqueduct through heavily populated areas at a tremendous cost or a river of proper quality at our door.

In weighing the many problems involved in this study, we know that you, Colonel Powers, and your staff will give us the benefits of your great knowledge and long experience for a possible solution of our future fresh water supply which is our sacred responsibility to the citizens of tomorrow, and I thank you very much for this opportunity to make this brief presentation and welcome you.

. . . .

We will next hear from the representatives of the State of Delaware, a general statement first to be presented by Mr. Richard A. Haber.

MR. HABER: Colonel Powers, ladies and gentlemen, my name is Richard A. Haber. I am State Coordinator for the Delaware River Valley Survey, and presently Chief Engineer of the Delaware State Highway Department and the Delaware Memorial Bridge. I am a registered professional engineer in several States and have practiced my profession for a period of 23 years. My appointment as State Coordinator was by Governor J. Caleb Boggs, and with the help of two assistant coordinators, Dr. A. J. Kaplovsky and Mr. C. O. Simpson, we have acted as a coordinating group for the information which will be presented here today.

We in Delaware have been fully aware of our existing water problems for some time, pending shortages and critical water needs in the not-too-distant future. Shortly after Hurricane Diane in 1955, we were informed that the Corps of Engineers was authorized and financed to make a water resources survey of the Delaware Valley Basin. Now, during the Delaware River Diversion Case in 1952 to 1954, we were confronted by the fact that the State of Delaware was in dire need of technical information with respect to its water resources. Since that time several of our State Agencies have been working diligently to accumulate such needed information.

We not only welcome the Corps of Engineers water resources survey, but also commend this organization for its progressive approach to have this study cover projected periods of 50 and 100 years hence. The State of Delaware has not only cooperated fully with the Corps of Engineers and the various Federal agencies designated to assist this survey, but also has undertaken the tremendous task of preparing an intrastate water resources survey to be included as an appendix to the overall Valley Report.

During the past two and one-half years our State Coordinators have been working closely with 28 different State interests, not only to coordinate the various facets directly and indirectly related to water resources but also to assure our people that a comprehensive evaluation is being made for the future. The progress made to date is most impressive.

The basis for such projective thinking is, of necesssity, different from the planning for present structures, with readily available assets, for the foreseeable future. In considering the needs for extended periods of time, the overall problems with respect to land use, land availability, population projections, economy, must be looked at objectively. Once the best thinking is obtained as to the scope of the needs and/or problems, then and only then, should detail be worked up to fit within this perimete projection. It is conceivable that too much short range planning at the present time, without due consideration of the needs 50 and 100 years hence, will prevent proper growth and development in the future. Adequate water is the key and this key must now be shaped in order to fit the lock to the future.

We have noted that the Resolution adopted by the Committee on Public Works of the U. S. Senate and which precipitated this hearing, in effect, states that a study be made to consider the economic and physical relationship of the structure to other works of improvement now being planned for the Delaware River Basin.

In order to clarify any misunderstanding which may have arisen from the notice of this public hearing, the State of Delaware at the present time is the proponent of a barrier study and not of a barrier. There is a marked difference.

We have received inquiries and comments amounting to prejudgement of what is anticipated without fully realizing that specific detail, based on a proper study, is yet to come, The barrier hearing notice requests specific information covering various aspects. In fact, we fully realize that other factors not included in the itemized list will, of necessity, require consideration during any study made. We have assumed, therefore, the intent was not to provide detail at the present time which could be derived best from an evaluated study.

The continuing statements will be made by the various gentlemen who follow, and Dr. Joel Kaplovsky will pick up at this point.

COLONEL POWERS: Thank you, Mr. Haber. Now, Dr. Kaplovsky, to discuss water resources and pollution.

DR. KAPLOVSKY: Colonel Powers, ladies and gentlemen, my name is A. Joel Kaplovsky, and I am a Registered Professional Sanitary Engineer. At present I am the Director of the Water Pollution Commission, and an alternate State Coordinator for the Delaware Valley Water Resources Survey. During the past 20 years my professional activities have been centered in domestic and industrial waste control. For the past nine years, since its inception, I have been directing the operations of the Water Pollution Commission.

A major portion of this Commission's activities has concentrated, for six of these nine years, on research with respect to studying the sanitary quality and self-purification capacity of the Delaware River estuary. During the past two years alone, we have completed more than 10,000 chemical and sanitary analyses on the Delaware River.

In my capacity as an alternate State Coordinator, I have had the opportunity to help evaluate Delaware's water use, projected needs and present and future quality. One cannot divorce water resources planning from primary consideration of quality of such waters, or, more precisely stated the contamination of these resources. Delaware's water resources outlook 50 years hence is bleak indeed.

In fact, the situation is so serious that long before this time we will experience a critical water shortage. Our present projections show, conservatively, the available surface and ground resources will meet only half our needs. Further, this projected availability is predicated on the rash assumption that our surface resources in Northern New Castle

County would be fully developed, and diversions out of the basins would not occur. Water from the Delaware River is our key to continued prosperity. Without this source, we would become a State unable to fulfill its inherent and proper potentialities with respect to our economy, growth and development.

Certainly, alternates for obtaining water down-river, aside from a barrier, are possible. Pipelines or aqueducts through metropolitan Chester and Philadelphia from upstream impoundments is an example; however, the costs involved would not only need careful study, but also the legal complications would be most interesting. On the other hand, a barrier would help recharge underground aquifers in upper Delaware and southern New Jersey, in addition to providing a surface supply.

One might, unknowingly, conclude that a barrier approval would require the solution of a staggering pollution complexity, whereas an aqueduct or pipeline would not. Unfortunately, future pollution complications are independent of either procedure.

Records are available from our neighboring states to show that during World War II this estuary was of extremely poor sanitary quality. Since the war, considerable effort and money have been expended toward improving the quality of this stream. Much has been accomplished; however, our findings clearly show that portions of this estuary must still be improved.

Ironically enough, the limitations with respect to improvement are not confined alone to the need for additional treatment in specific areas, but more to the lack of technology to do the job. It is conceivable for the present that if the maximum degree of treatment known were applied to these domestic and industrial loadings, the fullest of expectations for multiple use could be achieved. If technology of waste treatment should not make drastic progress in the very near future, the inevitable question arises, "what do we do with the wastes of our people and industry from the anticipated growth and development in the Delaware River Basin."

To avoid any misunderstanding, the technology of waste treatment has come far, and not too much reliance should be placed on the unknown entity that new methods would be derived in the future to handle this ever-looming problem. In fact, with increased peacetime usage of radioactive materials the situation could readily become even more critical.

"Old Man River" is already heavily burdened and additional loading will surely cause his collapse.

It is the belief and hope of many that low flow augmentation in the Delaware River through upstream impoundments will supply sufficient dilution to offset waste problems of the present and future. An expert witness for the State of Pennsylvania has stated during the Delaware River Diversion Case of 1952 to 1954 that "time is essential if full advantage is to be taken of the self-purification capacity of the stream." Thus, although the dilution resulting from flow augmentation is beneficial, the resulting decrease in time available for natural purification is deleterious.

The result, in effect, on stream sanitation may be helpful or harmful in any particular case. It will not be the same in all sections of the river. Our findings weigh heavily on the fact that the State of Delaware and southern New Jersey could conceivably become the recipients of decreased sanitary quality at increased flow regulation.

Investigators of other barrier studies have stressed numerous problems which would have to be resolved with respect to pollution control if a barrier were constructed. These investigations were primarily confined to effects upstream from the barrier; however, the problems for the State of Delaware and our neighbor, the State of New Jersey, would be notably below such a structure. It follows that the success or failure of most structures to regulate flow within the Delaware River Basin, and the inevitable increased water use, would be dependent upon the solution of the simple but all inclusive question, "What will we do with our wastes?" Dilution is not the solution to pollution. The presence or absence of the barrier in no way removes the necessity of providing, in the not-too-distant future, a drastic change in thinking for handling the pollution problem. With respect to pollution control, it is quite clear that both the economical and technological problems instigated by a barrier will be little different from the problems which will exist should no barrier be constructed.

With the intention of being repetitious, progressive thinking and planning are imperative. The need for drastic action with regards to pollution control in the future is inevitable.

It should not be construed that a barrier would or could be a substitute for upstream impoundments. The fact remains that a barrier dam is not a storage reservoir. It is entirely dependent upon upstream impoundments for maintaining its capacity during low flow periods. In essence, a downstream barrier could provide a means of making fuller use of already stored waters.

One would indeed be starry-eyed to assume, without a study, that the problems, pollution and otherwise, associated with a barrier would be minor. However, one would be equally wrong to assume that such a potential for the lower Delaware Basin would create, without a study, insurmountable problems.

It is firmly believed that one would be remiss as citizens and public servants of Pennsylvania, New Jersey, and Delaware, to ignore or condemn a barrier without a studied evaluation. It is, therefore, urgently requested that not only a preliminary barrier dam study be instituted at this time, but also that it be considered as an integral part of upstream impoundment planning for fuller water availability in the Delaware River Basin. Thank you.

. . . .

BRIG. GENERAL LACK: Colonel Powers, staff, ladies and gentlemen: I am Norman M. Lack, Delaware appointee to the Delaware River Basin Advisory Committee; a member of Governor Boggs' Water Study Committee; and

also on the Commission for Interstate Cooperation.

I have been asked by Governor Boggs to summarize the main points in the testimony just presented by officials of the State of Delaware. You have heard Delaware's case put forth by experts in several different fields. From the information these men have presented I am sure you will agree that our problem of obtaining a dependable and economic supply of fresh water for our citizens of the future is very serious. Our future economic and social welfare will be greatly affected by what we do now.

We face no simple task. The problems are complicated. The solution will require much time and money. It will not be easy to arouse a busy population or even our most thoughtful community leaders to the need of planning ahead in order to insure the availability of a commodity that is today generally available, and which most of us have come to take for granted. Yet this is what we must do.

In our search for a dependable and economic source of fresh water, we have considered many alternative possibilities. We must soon settle upon one possibility; one that has enough potential to warrant a comprehensive and detailed investigation.

Today, it appears that Delaware is called upon to show cause why one proposal--namely a salt barrier or estuarine dam--should be further considered.

We have been named as the proponent of this proposal and we accept the challenge. However, we would like to correct any misunderstanding of our position that may have been conveyed by the wording in the public announcement of this hearing. While we are indeed a proponent of the idea, we do not believe that the proposed barrier should be considered exclusively in relation to the needs of the State of Delaware.

The barrier should be considered in relation to the needs of the Delaware Basin as a whole, of which this State is but one part. The Senate committee resolution of April 28 of this year set the proper framework when it requested the Corps of Engineers to study "the economic and physcal relationship of such a structure to other works of improvement now being planned for the Delaware River Basin."

I would like to stress the following main points:

First: We are not recommending at this time that any particular barrier be constructed. We are asking for a study of the proposal.

Second: We believe the day will soon come when this basin will no longer be able to afford the luxury of wasting fresh water to the sea simply to hold back the salt front. To augment fresh water inflow for this purpose would, in our opinion, be only to augment the waste.

Third: We are fully cognizant of the several problems that a barrier might create, particularly with regard to pollution control, fish and wildlife, and water transportation. There is enough technical

evidence, however, to justify optimism that these important water use problems can, through careful planning, be solved to their own better betterment when coupled with the permanency of a barrier.

Fourth: We believe that a barrier may well prove to be the source of the greatest amount of fresh water, at the least cost, for the most people, especially in the heavily urbanized areas below the fall line.

Fifth: We believe that the creation of a fixed shoreline will greatly improve recreation facilities and will encourage the development of new waterfront industrial sites on both sides of the river.

Sixth: We believe that the increased depth of the river and the one-directional flow of the current, both of which would result from the barrier, will afford important advantages to water transportation, and to industrial water users, especially those requiring large amounts of water for boiler and cooling purposes.

Seventh: We believe that the barrier structure itself, if so designed, could serve substantially to reduce hurricane damages in the estuary by holding back the extraordinarily high sea water levels frequently produced by such storms.

Eighth: Finally we believe that a barrier reservoir draining approximately 7,000 square miles with its resulting huge storage, affords the greatest insurance to the most heavily populated areas and the largest industrial facilities within the Basin, and, in conclusion, Colonel Powers, we of Delaware respectfully request that the barrier study be made, if possible in time and money, with a positive approach by way of the merits of the future and not necessarily the faults of today. The small but the steady sea level rise, must certainly forecast a barrier of sometime in the future. Thank you.

23.05 STATUS OF BARRIER STUDY AS OF JUNE 1959

Unless it can be shown beyond doubt that the quality of water impounded in the barrier pool will be usable at all times for all purposes intended, as a source of supply for domestic, industrial and agricultural use, the barrier will not be feasible.

Basically a barrier can be erected to repel the salt water of the bay. If this be its only purpose, the geologic formation of the river offers no insurmountable problem relative to the construction of such a structure. However, the problem is not this simple as the activities of our civilization and the processes of nature offer or create forces which constantly tend to weaken or destroy the static situation caused by the erection of a barrier.

In analyzing the barrier, the effects of man's activities on the barrier and its pool must be studied, as well as the effects of the barrier on man's present and future activities.

If a barrier were constructed, provisions must be made for marine navigation to continue and serve the inland ports above the barrier. Basically two fundamental aspects are paramount and must be resolved if any such barrier dam is to be given further consideration beyond the preliminary testing stage. Since water supply and transportation are the primary issues involved, the preliminary studies must establish beyond question that salt water would not intrude significantly upstream from the structure or that water transportation would not be seriously impaired. The latter is dependent upon several considerations such as lockage time-loss, water velocity and height of tide.

Appendix E of the California Study states: "The intrusion of sea water into higher bodies of fresh water as a result of density currents is a phenomenon which was known to the ancient Egyptians. In 610 B.C. a proposed canal connecting the Nile River to the Red Sea was opposed on the grounds that sea water would climb upstream and contaminate the water used for irrigation in the Nile Valley.

"The remarkable force of density currents in ship locks is illustrated by modern experience at the Panama Canal. Within a short time afte the canal began operation in 1914, sea water appeared in Miraflores Lake, 55 feet above mean level of the Pacific Ocean, and the lake rapidly became too salty for domestic use. The inflow of sea water resulted from density flows in the multi-lift Miraflores Locks between the lake and the ocean. Similar experience has been recorded in other parts of the world, notably at the Lake Washington Ship Canal in Seattle, Washington; at the Charles River Basin in Boston, Massachussetts; at various locations in the Netherlands, particularly at the Ymuiden Locks of the North Sea Canal and the locks through the great Zuyder Zee barrier. All of these projects are analogous to a bay barrier, so far as the intrusion of sea water through conventional ship locks is concerned.

"The characteristic action of density currents in locks has been observed and measured in laboratory models as well as in prototype installations. Assume, for example, that a lock between bodies of saline water and fresh water is at a level of the upper pool and is full of fresh water, and that a vessel is to be locked upstream. The water level in the lock is lowered to tide level and the gates are opened. The interchange begins immediately, salt water flowing into the lock along the bottom and fresh flowing out along the top. Velocities are equal and opposite in direction. If the gates remain open long enough, a complete interchange will occur and the salinity of the water in the lock will be the same as that of the tide water. After the lower gates are closed, water level in the lock is raised to pool elevation. In this operation the water in the lock is diluted by filling water, the extent of dilution depending on the amount of lift. When the upper gates are opened, the process of interchange is repeated, and, given sufficient time, all the saline water in the lock will enter the pool"

Formulas have been developed and model tests have been made on this interchange but because of the complicated factors of mixing and friction, which cannot be expressed mathematically, formulas do not give accurate results. Other factors affecting the interchange of salt and fresh water

in locks depends upon the geometry of the lock, the difference in salinities of water below and above the barrier, and the length of time the gates are open. Actual quantities of saline inflow and fresh water outflow cannot be computed accurately. The principal of density currents have been demonstrated in the model of the Delaware River and Bay at the Waterways Experiment Station at Vicksburg, Mississippi.

Appendix E[4] of the San Francisco Barrier Study suggests the use of salt-flushing locks. The purpose of this type of lock is to prevent salt water intrusion into the fresh water pool by flushing the salt water from the lock prior to opening the upper gate. This would be accomplished by introducing fresh water into the lock at a high level in the lock and at the same time remove salt water from ports in the floor of the lock. By using a sufficient amount of fresh water for flushing, the salinity in the lock would be reduced to a point where the density head between lock and pool would be so small that the resulting density current on opening the upper lock would be very weak.

It is evident there will be salt transfer through the locks. How many tons will be transferred in a given time must be determined by a model study of the particular site and the present and future tonnage which will pass through the lock.

To quote from the San Francisco Barrier Study[1]: "Theoretically this transfer of salt water could be avoided if salt-clearing locks were provided instead of the standard navigation locks. No salt-clearing lock however, has ever been built and the only evidence that the use of such locks would prevent transfer of salt water into a barrier pool comes from laboratory tests."

Salt water flowing from the lock into the barrier pool will travel upstream in the shape of a wedge of diminishing height and velocity. This action will continue until a state of equilibrium is reached. The distance traveled upstream may be several thousand feet or more, depending on the downstream flow of fresh water.

The San Francisco Barrier Study[4] recommends that the "slug" of salt water be stored in a sump immediately upstream from the barrier. The salt water thus trapped is returned to tidewater by means of a gravity drain leading from the bottom of the sump. The salt water drainage system of the Lake Washington Ship Canal is the best example to date. However, the sump and drain do not remove all the salt water because of their capacity.

The report recommends the salt wedge be channeled to the sump in the upper pool. The elevation of the sump would be lower than the surrounding pool bottom. The present excavated channel of the Delaware River may not be feasible for a sump because in times of drought the flow of the river may be such that the "slug" would move beyond the theoretical sump area and extend upstream so as to not be removable by the drainage system.

It is evident, at the present time, that the salt wedge is eroded into the upper layers by wind and waves, ship propellers, and the friction of fresh-water flows. These effects cannot be computed mathematically. However, it is estimated in the San Francisco Barrier Study that as much as 10 percent will be dispersed into the pool.

In order to flush the locks and the salt water sump, fresh water is withdrawn from the barrier pool. The amount withdrawn will be a function of the tonnage passing through the locks. In the Delaware system consideration must be given to the tonnage in 2010 and 2060. This results in the problem of increasing salinity behind the barrier. Consideration must be given to the fresh-water flow, especially controlled flows, the water withdrawal, the loss through evaporation, and the loss from flushing the locks. Unless a sufficient amount of inflow occurs, salinity may build up in drought periods so that the concentrations of chlorides exceed the permissible limit of 250 ppm set by the U.S. Public Health Service in 1946 as a part of its drinking water standard.

From recent (Spring 1959) experimentation on the Delaware River Model at the Vicksburg, Mississippi, Waterways Experiment Station, sponsored by the Corps of Engineers, Philadelphia District, certain summary observations may be made. Admittedly, lack of sufficient funds and time prevents an extensive testing program with regard to the feasibility of a barrier dam in the lower Delaware River. However, several significant factors, indirectly related to the barrier structures tested, were emphasized by the experimentation.

Essentially two barrier structures were tested at the Waterways Experiment Station. One structure, plan A, was without locks, whereas plan B contained ship locks. Plan A was unable to prevent the salt front from moving upstream, whereas plan B, with the aid of a scavenger pool, was able to prevent salt, for all practical purposes, from contaminating the upstream pool. Unfortunately, as pointed out previously, lack of funds and time prevented a more extensive testing procedure.

Several interesting and pertinent principles were emphasized through this experimentation. The degree of influence could be modified by varying the size, shape, and/or location of the barrier structure but the principles involved would remain essentially the same. Any barrier-type structure in a tidal estuary which modifies the normal tidal oscillation produces, downstream from the structure, a lower low tide and a higher high tide. Upstream, under plan A, the reverse is true. Under plan B, a stationary pool would exist upstream and the water elevation would be governed by the height of barrier spillway. The relative range in tide is not only controlled by the type of structure but the range varies throughout the estuary.

Results of the present studies on the model indicates the average high tide will increase about 1.8 feet in elevation at the barrier and the low tide will be approximately 1.6 feet lower. As a result of this it may be necessary to increase the elevation of the barrier. Excessive increase of the water level of the pool could cause difficulty as present wharfs and underground installations, such as sewer outlets, are designed for present high tide levels. Such structures would need modification which would involve additional construction costs. Many of these structures have a limited life and will necessitate rebuilding in the future. It may be necessary, in specific locations, to construct levees or raise levees to protect adjacent lands.

A lower low tide at the barrier may require redredging the existing channel below the barrier in order to conform with regulations governing the depth of channel. Conversely increase in pool elevation may decrease dredging of the channel above the barrier. However, there will be a tendency for increased sedimentation behind the barrier which would necessitate additional dredging.

A barrier system as a source of water is incomplete in itself due to related factors. The quality of the water to be obtained from the barrier pool is of utmost importance. The Office of Business Economics report clearly portrays the expansion which will occur in the valley with regard to population and industry. Unless proper measures are taken, the water quality in the river will deteriorate below its present condition. It was shown in Section XIX that the pollution recovery capacity of the river will not only reach its limit in the near future but a new approach, in all probability an interceptor sewer to the ocean, will be needed in the near future to solve the impending waste problem complexity. Solution of the waste problem, irrespective ofthe barrier system, will necessitate a segregation of the difficult-to-treat wastes for discharge into an interceptor system. This procedure would in turn decrease the pool elevation if sufficient flow augmentation were not practiced. A barrier pool with its fixed shoreline is not compatable with uses which would involve a lowering of the pool elevation and increasing the detention time behind the barrier. Additional augmentation would insure a shorter detention period behind the barrier and thereby reduce any potential stagnation.

From the viewpoint of national defense, many problems must be faced. It has been clearly shown in past wars that no nation is at all times invulnerable. In the Port of Philadelphia is the Navy Yard, and there are many other industries which depend on marine navigation for supplies. By 2010 and 2060 these industries will increase many fold on both sides of the river. If the lock system should be rendered useless in time of war it might be necessary to breach the barrier as an emergency measure to maintain navigation. However, if by this time essential industry had become dependent upon the barrier pool as a source of water the condition created by the breaching of the barrier would be critical. War industry may be retarded, or even stopped, until an alternate method of obtaining water could be found. In case of war there is little doubt that many restrictions would be imposed which could have a controlling influence on the feasibility of the barrier. Past records have indicated a lowering of the quality of the water in the river during a war period. This can occur again depending on the pressures affecting certain problems arising in times of emergency. This inherent vulnerability, however, is also present for other reservoir sites such as those of New York City and any potential sites of the future. The barrier pool could be rendered useless from radioactive contamination incident to an atomic attack nearby. However flushing of such contamination from the pool area could conceivably take place more rapidly than under tidal conditions.

The period of time the barrier must be in place before the water can be useable would become a factor. The period of adjustment may be several years before water in the pool could become satisfactory for use. If the barrier is to be built this factor will affect the programing of

the construction in order that the supply of water would be available when the demand arises.

The barrier pool is not a water conservation measure and will not provide means for storing flood waters. Stored water from reservoirs on the Delaware River and its tributaries must be continuously supplied in periods of drought to augment low flows. This would become an integral part of the overall water plan.

Due to the urgent need for water in the near future, the State of Delaware has become a proponent of a barrier study. The purpose of such a study to determine if it is a feasible method to obtain water. Review of literature on the subject and present experiments point to some of the difficulties associated with the problem. Further study and research may find solutions to the problem.

It is clearly understood that many problems, which could involve a heavy outlay of funds, should a barrier dam be constructed, would need full consideration. It is firmly believed that these problems are solvable technically, however, unless the salt-water invasion and the navigation phases are determined to be solvable technically, consideration of other problems initially appears superfluous.

A favorable benefit-cost ratio would become the primary consideratio and/or solution for many related problems. We must not lose sight of the fact that a barrier structure is a consideration for the future and an extensive period of time does exist to resolve many of the immediate problems. However, it is fundamental that if the Comprehensive Water Resources Survey is to be truly comprehensive in consideration of the water needs 50 and more years hence, projected thinking and planning can not and must not be set aside now.

It is evident that a full evaluation of the barrier dam feasibility must involve broader considerations initially before a decision can be made as to whether such a potential should be given further study. The ever-recurring question arises as to whether adequate water could be obtained in sufficient quantity and economically other than from a barrier system to supply the projected needs downstream. Obviously such a decision is of paramount importance simply because the comparative value of water will be established and thereby effect the benefit-cost ratio. Further, if other means of obtaining sufficient fresh water downstream is not provided the comparative value and importance of a barrier structure immediately assumes considerably greater significance.

Until such time as a definitive answer can be obtained the Corps of Engineers must recommend and justify an alternate plan for supplying not only the State of Delaware with water but also other users in the lower Delaware River Basin.

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SECTION XXIV

REVIEW OF FACTORS AFFECTING SALINE WATER CONVERSION

24.01 GENERAL

The total salt concentration in sea water[1] lies between 3.2 and 3.7 percent; it is usually given in round figures of 3.5 percent. Accordingly, it might be supposed that the water would also vary with respect to the relative concentrations of the individual dissolved salt, however, this is not the case. Sea water is composed of approximately 96.5 percent water and 3.5 percent dissolved salt. Both water and dissolved salts are natural resources. Water is usually classed as saline when the total amount of dissolved solids exceeds 500 ppm. Such water is relatively soft when compared with sea water, which contains about 35,000 ppm.

The recovery of fresh water from sea water, except on a small scale, as on ships at sea or in lifeboats, has until recently received comparatively little attention, but in recent years it is being investigated thoroughly.

When fresh water achieves the status or value of food itself, the price to be paid to obtain such a commodity is of secondary importance. Under such circumstances, where possible, the conversion of salt or brackish water to fresh water is a matter of technical ability and not an economic consideration. Further, the price of fresh water over the world may vary from essentially no cost whatsoever to a commodity considered as expensive as determined by supply and demand. In areas where water is plentiful there is little consideration of the cost involved. However, in arid regions and on many small islands surrounded by the sea, the need for a fresh water supply overshadows its cost.

Various techniques for producing fresh water from salt water have been known for many years. Primary efforts in the last decade have been directed toward desalting water at a reduced cost, so that it may be competitive in cost with sources of fresh water under specific conditions. At present it is estimated that large scale conversion units may produce fresh water at 50 cents per thousand gallons in the near future. Whether this cost applies at the source of supply or at the point of consumption is not made clear. This cost, compared to the 1955 cost of excess water in Philadelphia at 9 1/3 cents per thousand gallons ($93.00 per million gallons) delivered to the consumer, is excessively high.

Multiple-effect distillation[3] of sea water has been used in the production of fresh water since 1933. A plant in Curacao, Dutch West Indies, was started in that year and is producing 600,000 gallons per day. Both Curacao and Aruba have depended upon distilled water for more than 20 years. Another distillation process has been in use since 1952 on a still larger scale in the Persian Gulf sheikdom of Kuwait. The four existing installations can produce about 1.2 million U.S. gallons a day. Plans are under way to produce 2.4 million gallons daily in another plant.

The latest distillation plant in operation is in the Dutch West Indies Island of Aurba. This plant has a designed output of 2.7 million gallons a day.

Coalinga, California, is actually the first U.S. city to have a municipal desalting plant. Its present capacity is 28,000 gallons per day, for its membrane process plant. The cost per 1,000 gallons at this plant is expected to be less than $1.00, namely, 15 cents for electricity and from 40 to 80 cents for maintenance and replacement of membranes. Previously this community had to haul its water a distance of 45 miles by railroad tank car. Under the old system the freight charges averaged $7.05 per 1,000 gallons.

There is little doubt that salt water conversion will play an increasingly important role as a source of fresh water in the future. The immediate major decision to be made is an estimate or evaluation of how significant salt water conversion may become to the State of Delaware. Consideration is largely dependent upon the comparison of the need and cost of the water, namely, whether salt water conversion will become economical and/or competitive with other fresh water sources available to other users in the Basin.

It is of interest to note that in the State of California[5] water shortages have been critical issues for some time. Active planning to expend several hundred million dollars to obtain water from a location 500 miles distant from its intended consumer (Los Angeles County) has been under consideration for some time. The question arises as to why such a broad and extensive plan is being pursued in the light of the apparent optimistic cost estimates for salt water conversion when carried out on a large scale.

A fact which cannot be ignored is that it is difficult for competitive interests to pay for water at 5 and 10 times the cost paid by others. This is the dilemma confronting the State of Delaware, namely, whether a source of fresh water supply from saline sources can be obtained at a cost which is competitive with that of other localities.

Unfortunately, all potential users of converted saline water would not be adjacent to ocean sites. The disposal of the brine residue from salt water conversion in inland areas or upper estuaries presents a serious problem. The cost of power for such salt water conversion is a critical issue as it may be quite variable from location to location.

24.02 SALINE CONVERSION

Basically, there are two ways to obtain fresh water from sea water, namely, demineralization, or ion exchange, and distillation.[1] Demineralization of natural waters is usually not used in the purification of waters of high salt content because the costs rise in proportion to the concentration of dissolved salt. The prospect of recovering water from sea water by distillation has been greatly enhanced by the development of the vapor-compression still. Even so, in order to make it economical for sea-water distillation the salts in the residual brine must be recovered as byproducts.

The composition and properties of sea water are well known. No new exploration techniques need to be developed.

Resources for Freedom[1] states "The two most significant new technological developments applicable to sea water are ion exchange and vapor-compression distillation. Ion exchange materials may be tailored to extract selectively the various ions that occur in sea water. This process should see marked development in the application to sea water during the next 25 years."

a. Demineralization. The chief cost in demineralization is for the regenerant needed for the ion exchangers. The regenerant waste cannot be discharged into a sewer when using a sea water demineralization plant. Further, the regenerant salts would have to be recovered in order to operate the plant economically.

The regenerants needed for the demineralization processes may be either (1) an acid which in the present instance probably would be hydrochloric although sulfuric is not entirely out of the question; or (2) an alkali such as soda ash. It is improbable that these materials can be recovered except as sodium chloride or sulfate, both of which are low-value products.

As recently as 1952, the statement[1] was made that the above analysis does not provide a very hopeful picture for demineralization as an economical process to produce potable water as the primary product from sea water. The alternative is water as a byproduct from other operations such as a specific element recovery process.

b. Distillation. Recovery of water from sea water by distillation depends on: (1) a cheap source of heat; (2) an efficient distillation plant; and (3) byproduct recovery of salts from the distillation concentrate.

The present common fuels are coal, oil, and gas. Other energy sources are: (1) waste heat from other operations of the same plant; or obtained by integration with other plants, such as atomic breeder piles; (2) nuclear energy; (3) geothermic energy; (4) tidal energy; (5) degraded energy by way of the heat pump; and (6) solar energy.

By use of vapor-compression distillation it is possible to obtain pure water and high concentration brines from sea water at a low cost; the latent heat of water is used to heat the still in this process. This is accomplished by compressing the vapor, thus raising its temperature, the vapor then being circulated through heating tubes.

"It is estimated[1] that up to 25 times as much water may be obtained per pound of fuel by vapor-compression distillation as can be obtained by single-effect evaporation. The estimated cost lies between 3 and 10 times the present cost of municipal water without recovery of sea water salts. When the salts are recovered and the salt recovery process bears some of the cost, the ratio becomes much less."

c. <u>Comparative Cost</u>. "Estimates[1] for sea water distillation, using diesel fuel, range from 24 to 28 cents per 1,000 gallons. Another estimate, with fuel unspecified, is 20 to 30 per 1,000 gallons. This takes no account of labor and investment costs, which would raise the total cost from 70 cents to $1.00 per 1,000 gallons." It should be noted here that the above costs are those of 1952 and must be adjusted accordingly to correspond to present-day costs.

The national salt water conversion picture was summarily reviewed in Volume 4 of Resources for Freedom[1] as follows: "This cost is not out of line with costs of making distilled water from raw fresh water. The costs of distilled water vary over a fairly wide range, roughly from less than $1.00 to well over $10.00 per 1,000 gallons, depending on the fuel and the type and size of plant. The larger and more efficient the distillation plant, the lower are the costs. The cost of water obtained by distillation from sea water is, however, materially higher than the present cost of water that is available for municipal and industrial use.

"Median figures for water rates (1952) in the United States run from about $1.90 per 1,000 cu.ft. for 1,000 cu.ft. consumption per month, to 75 cents per 1,000 cu.ft. for 1,000,000 cu.ft. consumption per month. This is 27 cents and 10 cents per 1,000 gallons respectively.

"If water from sea water is to compare with present water supplies, the mineral salts in the distillation brine must be recovered. Byproduct processes are used on brines from solar evaporation of sea water in California ... Unfortunately, very little information has been published on the costs of production.

"When the distilling costs are subtracted from the value of the salt in the brine, it appears that the salt recovery process will have to bear a surcharge of 43 to 90 cents (assuming a distilled water cost 70 cents to $1.00 per 1,000 gallons). The margin between this and the market value of $3.35 is about $2.45 to $2.90 for salt recovery costs and possible profits. The prospect for distilling sea water economically appears decidedly brighter than does the possibility of demineralizing water at a reasonable cost."

In a recent article[2] Mr. Sheppard Powell stated that he predicts sea water containing 35,000 ppm of salt will be converted into fresh water as cheap as 50 cents per 1,000 gallons. Present costs are more than $2.00 per 1,000 gallons. It was further reported that a recently developed freezing method is estimated to cost about $1.00 per 1,000 gallons to produce 500 ppm fresh water from sea water. This may be compared to the predicted cost of $1.00 per 1,000 gallons or less for distillation of sea water by multiple-effect evaporators. With respect to distillation, relatively high capital and operating costs have showed widespread adoption of evaporators, which can be integrated with the generation of electric power by steam stations. Present costs of producing fresh water from the sea varies from $2.00 to $3.00 per 1,000 gallons without credit to power generated or other benefits. Mr. Powell also states that by using less costly metals for the special alloys, and by controlling scale formation, the cost can be reduced to 50 or 60 cents per 1,000 gallons.

The author further indicated that a 50-cent per 1,000 gallons cost now can be acheived for a 10 mgd plant employing the evaporation process.

Evaporation, except for solar heat, is uneconomical for salt producting and cannot compete with production of the same salts and other elements by other methods and from sources other than sea water, such as well brines and mineral deposits. Possibly, by this operation water could become a byproduct.

d. Mineral Recovery. "In recent years[1] there have been a number of significant developments in methods for recovering minerals from sea water. Unfortunately, very little about costs has been make public so that it is difficult to judge the economic factors. Some of the developments in the field of mineral extraction have been applied industrially and are in operation today so that, at least locally, they may be presumed to be profitable. So much depends on locally available supplies of raw materials (other than sea water), power, fuels, and other items, that comparisons are difficult to make."

24.03 SUMMARY OBSERVATIONS

It is difficult to comprehend how two adjacent users, namely, one using fresh water and the other desalted water, could pay or be charged an equal amount when the water is obtained locally. Continued emphasis is being made on the breakthrough in that new techniques and improvements are being designed every year to make converted sea water more palatable and/or equivalent to fresh water sources. The question arises whether if such an effort were expended toward present fresh water treatment processes, would not the cost of such fresh water be even less than the cost of present production? It appears probable that savings could be made in the cost of supplying fresh water to the present-day consumer if a similar all-out research program were devised. This would of necessity make the two sources less competitive.

A most significant point brought out by Mr. D. H. Huff,[4] Executive Officer, Department of the Interior, is that numerous local problems must be resolved to obtain or convert fresh water from brackish water. This particular phase would apply to the upper reach of the tidal estuary. The problem of salt waste disposal is far more serious than is readily apparent. The salt brine could not be placed on the land because it would, in all probability, contaminate our ground water resources, and, local streams being extremely small, could not receive the brine waste without creating a serious problem. Consequently, the problem looms ever large, in that if conversion is to be used without too much difficulty in the lower Delaware River, it would have to be located in areas adjacent to waters highly saline.

It is conceivable that the problem of cost with respect to domestic supply is not as critical as it would be for other uses such as agriculture and industry. In these activities Delawareans are faced with a competitive market, and any additional costs of the water supplied must be reflected in the consumer's product Unless an economical supply of water for industry and agriculture can be supplied, salt water conversion for general use can not be a reality but merely an emergency source which will remain as a small scale operation.

If waters have to be transported a great distance, it is conceivable that salt water conversion could become competitive with costs for treatment of fresh water. The State of Delaware becomes doubly vulnerable if reservoirs for holding water are constructed considerable distances upstream instead of downstream, as behind a barrier. Transporting water from upland areas could be so expensive as to force Delaware to assume, as an emergency measure, the taking of water from the sea, which in turn would make Delaware's position non-competitive. It is quite apparent that a structure such as the proposed barrier dam could become extremely important to the State of Delaware in order to maintain fresh water resources downstream and thereby provide water economically to the people of the State of Delaware.

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SECTION XXV

STATE PARK COMMISSION

25.01 INTRODUCTION

The overall situation of the park and recreation problem in the State of Delaware indicates that at present it is in a fluctuating state. This, in many aspects, is a period of transition towards what hopefully will be a broader acceptance by the public of the importance of recreation as a public service in our State.

To a large degree, this state of fluctuation is the result of the increased citizen interest and awareness of what Delaware offers, now and potentially, in terms of well-developed, attractive, soundly-administered parks and recreational facilities.

In New Castle County, this interest has taken the form of increased recreational demands by an exploding population. These expressions were the impetus for several professional and professional-lay studies of recreation needs, needs now and in the foreseeable future. To mention only two instances of such work: In 1956, and again in 1959, the Allen Organization,[1] a professional recreation planning firm, prepared and published analyses of Northern Delaware's park situation; and in 1957-58, the Welfare Council of Delaware used recreation specialists and volunteer committees to compile an extensive study of leisure time needs and services in northern Delaware.[2]

Similar evidences of demand are apparent in Kent and Sussex Counties Citizen, service clubs, and the Chambers of Commerce in the cities of Dover, and Rehoboth have publicly announced the need for additional recreational facilities and the importance of preserving and developing Delaware's ocean beach lands for the public.

Such efforts are welcomed by and are encouraging to the State Park Commission. They are, also, important examples of the changing atmosphere currently eveloping Delaware's recreational future.

The term "recreation" has broad connotations and many interpretations. Recreation can be of the restful type generally known as "loafing"; it can be of the intellectual type, such as music and art appreciation, sightseeing, etc.; or it can include active participation in sports and games. It includes the nature and facilities of parks on city, county, state, regional, and national scopes; it includes hunting, fishing and boating. It encompasses public and private centers such as historical sites which attract sightseers and tourists; and its meaning to cover cultural centers such as museums, dramatic, musical, and artistic facilities, whether publicly or privately owned.

The wide inclusiveness of the subject requires, for this water resources survey, some restricting and limiting discussion before any factual presentation.

The method in Delaware of administering recreational facilities, for example, is applied in varying degrees of responsibility by a number of governmental bodies; the State Board of Game and Fish Commissioners, State Forestry Department, Public Archives Commission, State Highway Department, numerous private individuals, agencies, corporations, and institutions, as well as municipal authorities and units of county governments.

For these reasons, then, this State Park Commission report will deal with only those areas which are under the State Park Commission's authority, and are considered qualified potentials for immediate acquisition and/or development as state parks.

For further clarification the fundamentals of a good state park and historical site set forth by the National Conference on State Parks[3] are:

"1. Quality. Some natural, inspirational landscape or of historical/archaeological significance with a foreseeable future of attractiveness for public enjoyment if adequate protection and improvements are made available.

"2. Adaptability. The area should adequately permit proper protection, development and administration. Quality and adequacy of water supply for bathing should be investigated.

"3. Distribution. Geographical location, related to concentrations of population, is important to provide adequate recreation opportunities within an accessible area.

"4. Balance. A logical balance of areas providing diverse recreational opportunities is favored, considering those areas under other governmental agencies.

"Supplemental factors in evaluating acceptable ingredients of a state park include size. Such sites should be relatively spacious, preferably 500 acres or more, of outstanding scenic or wilderness character ... (and) all commercial exploitation of resources should be prohibited.

"Since natural scenery and objects of historic or scientific interest are where you find them, selection of such areas on a geographical basis may not always be possible. Logical balance among the parks of a system, on a geographic basis, should be sought so that a well-rounded pageant of the state's natural and cultural heritage may be preserved and presented to the public.

"Areas of extraordinary value, however, should be selected regardless of balance. Distribution in relationship to large cities and concentration of population should be recognized, the element of use by the people is one of principal consideration, and the selection of a site that will be visited by thousands of people each year is to be preferred to one that is remote and visited by only a few."

This Section then, will present facts regarding State parks on both the actual and the potential basis, including those administered by other agencies, covering the direct relationship of water and water resources to recreational facilities existent today and those proposed and/or possible within the next 50 and 100 years. (Domestic water needs are not computed.)

25.02 SCOPE OF STATE PARK COMMISSION

Authority as defined by Delaware Statute.[4] The purpose of the Commission is to preserve and protect the scenic, historic, scientific, prehistoric, and wildlife resources of the State, and to make them available for public use and enjoyment.

The Commission may acquire lands, make and enforce regulations relating to the protection, care and use of the areas it administers, and in cooperation with other agencies, or on its own motion, make studies of the recreational facilities now available, and of the recreational needs of the state to determine what is not now available for public recreation and should be acquired.

25.03 PARK AREAS AND FACILITIES ADMINISTERED BY THE STATE PARK COMMISSION

a. Brandywine Springs State Park.

(1) Characteristics and facilities. Located on the suburban edge of Wilmington, this 59-acre park is easily reached by State Route 41, which forms its western boundary. It offers 115 tables and 25 fireplaces for family picnicking, two picnic pavilions for groups of 50 to 200, two softball diamonds, and a day camp site.

(2) Water resources. Red Clay Creek and one of its tributaries, Hyde Run, pass through Brandywine Springs, but because of pollution these waters support little living marine or plant life. This same supply is unusable for any truly recreational purposes such as swimming. Domestic water needs are purchased commercially.

(3) Proposed development. Enlarged picnic facilities, a swimming pool or pond, extension of the existing park roads, and development of a site for nonadult camping are additional facilities planned by the State Park Commission.

(4) Public use. Because of its size, 59 acres, Brandywine Springs is limited in the amount of recreational facilities it can provide Its nearness to the heavily populated cities of Wilmington and Newark, place a heavy demand on the park and in 1958 its estimated attendance was 40,000. When fully developed, through careful planning the visitor capacity of this area will be 100,000 per year.

b. Fort Delaware State Park

(1) Characteristics and facilities. Located off Delaware City on 160-acre Pea Patch Island in the Delaware River, this former Federal prison for Confederates captured during the Civil War, was acquired by the State in 1947. Vandalism erosion, and lack of public interest in preservation took a heavy toll until a recent program was launched by the State Park Commission to halt the inroads of neglect and the elements. The Fort has many examples of fine masonry craftsmanship in its granite walls and interior brick work. Some restoration work is now being done. A 10-acre picnic site and lawn around the Fort and moat are maintained for the enjoyment and convenience of visitors.

(2) Water resources. With the exception of limited boating and hunting, Delaware River waters in the vicinity of Pea Patch Island have a low potential for recreation. Present water quality and the murky condition of the water eliminate the possibility of bathing.

(3) Proposed Development. The primary value of Fort Delaware as a unit of the State Park System is concerned with its historical significance. It is the objective of the Park Commission to make necessary structural repairs and improvements in order to preserve the Fort as an historical monument, and to make it safe and accessible for visitors.

(4) Public Use. In 1958, Fort Delaware State Park had an attendance of 2,124. It is estimated that 50,000 per year would be attracted if the structure were properly restored, adequate public boat transportation available, and a self-guiding tour system provided.

c. Trap Pond State Park

(1) Characteristics and facilities. The principal attraction within the 928 acres of this park, located six miles east of Laurel, is a 95-acre pond around which picnic, camping, and swimming facilities are located. Natural scenic values are present in over 500 acres of pine forest and cypress swamp. From a recreational point of view, Trap Pond is the most significant unit in the State Park System in that adequate resources and land are available to meet present recreation needs within the area it serves.

(2) Water resources. Only Trap Pond State Park contains what might be termed an adequate margin of recreational water reserve. The quality of this water is acceptable and the quantity is sufficient to warrant expanded park use in all facilities. There is, however, no water reserve for any type of consumptive use. Each year since its development the park has continued to grow in popularity and attendance, and in view of this increasing demand, there is no surplus of surface water according to the best park standards and practices.

(3) Proposed development. Full development of this park should provide ample space and facilities for intensive day and extensive weekend and vacation activities. The development of the park is proceeding in accordance with a sound master plan prepared in 1956 by the State Park Commission in cooperation with the National Park Service.

d. Public use. During the 1958 season 150,000 persons visited Trap Pond. The visitor capacity of this area could be increased to 450,000 without adversely affecting essential park values.

25.04 DELAWARE'S STATE PARK POTENTIAL

a. Problems. Several fundamental difficulties overshadow every element of park and recreation planning in Delaware.

(1) There are not enough suitable publicly-owned lands or developed park areas at the present to satisfy public demand and needs. Any serious planning for the next 50 and 100 years is contingent upon immediate acquisition of suitable additional land for recreation purposes. Such a step is already overdue. "Land use is changing almost overnight and unless some positive action is taken soon, there will be no land left for recreation. Acquisition of land for parks has all but stood still in Delaware."[2]

(2) Nearly all forms of recreation, whether present or possible, hinge directly upon the availability of adequate water for specific activities.

The relationship of good recreation facilities is for all intents and purposes, inseparable from enough suitable surface water. There is no doubt as to the public demand for recreational opportunities contingent upon water. A study of outdoor recreation activities and preferences of the population living in the Delaware River Basin[5] shows that swimming was rated first as a required day's outing attraction, and first among the most desired vacation activities. Even more emphatic is the survey's poll which placed swimming, beach visiting, fishing, and boating as the first four out of sixteen vacation preferences, all impossible without large bodies of water.[6]

b. Immediate State Park Commission Plans. The Commission proposes immediate inclusion of the following sites within the State Park system:

(1) Lum's Pond. This is a 1,500-acre site in central New Castle County, north of the Chesapeake and Delaware Canal, 16 miles southwest of Wilmington. The 200-acre pond, second largest in the state, has a nine-foot average depth, and is of good quality. The irregular character of the shoreline is such as to provide good sites for development, including beaches and boating facilities. Its location and limited access roads provide easy accessibility for 4.5 million people within 50 miles.[7]

In view of the small amount of recreational acreage convenient to the growing New Castle County population, an area experiencing a 37.7 increase in residents between 1950 and 1957,[8] the State Park Commission has given Lum's Pond priority on its list for early acquisition.

(2) Ocean Beach Lands. State Park Commission administration of the estimated 2,900 acres of state-owned beachfront from Cape Henlopen to Rehoboth, Dewey Beach to Indian River Inlet, and in the Fenwick Island vicinity is of prime importance. Limited development has already been carried out in these locations.

It is recommended that the Delaware seashore and coastal area be preserved and developed as a recreation area for uses appropriate to a seashore environment. It is one of the last remaining undeveloped public beaches on the North Atlantic coast.[9] There can be no question of its tremendous value for recreation, and it will continue to be Delaware's No. 1 recreational asset for residents and tourists alike.

(3) State Park in Kent County. Increasing sizes of various cities in this central county make it imperative that a suitable state park site be acquired and developed. Such an addition, in terms of sound potentials, would give a more equitable balance to the state park system. While Kent County has large national and state wildlife areas, Bombay Hook and Petersburg, it currently lacks a large area devoted entirely to multiple recreation use.

It is proposed that a portion of the Murderkill River Watershed be acquired with adequate water and land acreage to serve the immediate and potential recreation needs of this area.

A site on the Murderkill River would be within 25 miles of some 75,000 Delaware residents, and approximately one and one-half hours maximum traveling time from any part of the state. Equally important, the cities of Dover and Milford are 10 miles or less distant.

Water quality of the ponds located in the Murderkill watershed is good, offering facilities for swimming, fishing and other forms of recreation. This water resources possibility is pertinent to Kent County's recreational future.

25.05 WATER RESOURCES AND DELAWARE'S FUTURE STATE PARK ACREAGE

a. Preference for parks with water facilities. Water Areas have special appeal to man--visit any outdoor recreation area ancd watch the people. Seldom do they scatter evenly throughout the park but instead tend to cluster in certain spots, most often near the water's edge. The pleasures of picnicking and camping are much enhanced when they can be pursued along a lake or ocean shore.

Bathing is still the prime attraction of a park. It is very difficult to incorporate a body of water or shoreline in a park at a cost that can be afforded, and to find one with adequate safe, natural water for high-capacity bathing use is rare indeed.

Artificial developments are costly. It is hardly worth building a pool in a park less than 8,000 square feet of water surface, and in round figures such a pool would cost approximately $200,000.

The sad part of this is not the cost, but the fact that we can still accommodate only relatively small numbers of people. Pools do not satisfy for the big-use days like natural beaches.

Next to swimming, probably the second greatest public demand is for picnic facilities. Picnickers also want to be near water, especially during the hot dry summer months in Delaware.

Picnicking and swimming invariably go together in a State park development and modifying existing ponds opens up the possibility of providing facilities for both. Construction of a swimming pool provides for a limited number of swimmers, but it does not provide the water attraction that is desired by the picnicker.

Recreation in its broad aspects encompasses a wide field of which water recreation uses are an important phase. Management, development, and control of water resources must take cognizance of many beneficial water uses, among which is recreation.

b. Estimation of water requirements for recreation. Water for recreation and aesthetic values are quite distinct from that for domestic consumption and sanitation purposes. This report considers only the first category.

Under nationally-accepted standards, each state park should provide 10 acres of land for every 1,000 residents within the area it serves, plus additional acreage in outstanding natural resources for recreation such as beachfronts, which attract a higher percentage of non-resident visitors.

A minimum of 10 percent of such areas (acreage) should consist of water surface for complete recreational purposes. Only Trap Pond meets the minimum of the three sites presently under the control of the State Park Commission.

A number of professional park planners are now basing their projections on a standard of 15 acres per 1,000 residents within the area served by the park.

We can determine how many people can use a designated picnic area, campground, or bathing beach, but in so doing we ignore the subjective values, the personal feelings of the users about such crowding. Who is to set arbitrary limits on the acreage of land and water that should be set aside to preserve recreation resources? We know that where more people crowd into a park the more the intangible satisfaction and refreshment one receives from being out-of-doors is apt to be lost. The location of the parks, the topgraphy, plant life, the use of surrounding lands, and many other factors influence the amount of land needed.

c. Estimation of land requirements for recreation. Under the 10-acres-per-1,000-persons formula, Delaware should now have 4,580 acres of state park land for recreation. The state actually has 3,887 acres which could be so classified, excluding historical sites. This includes Brandywine Springs, 59 acres; 2,900 acres in ocean beach lands, and Trap Pond, 928 acres..

(1) Population estimates for Delaware in the years 2010 and 2060, used in the Economic Base Survey of the Delaware River Service Area, are 1,426,400 and 3,352,100 respectively.

Under the same 10-acre formula for state parks Delaware should have:

In 2010: 10 x 1,426 = 14,260 acres (22.3 sq. mi.) of state park land.
In 2060: 10 x 3,352 = 33,520 acres (52.5 sq. mi.) of state park land.

(2) Using the 10 percent water surface minimum for recreational use, these future years would then require the following amounts of water for this purpose only:

In 2010: 10% x 14,260 = 1,426 acres (2.23 sq. mi.) of water for recreation.
In 2060: 10% x 33,520 = 3,352 acres (5.25 sq. mi.) of water for recreation.

Figures supplied by the U.S. Geological Gauging Station at Trap Pond show an average discharge of 13,770,000 gallons of water a day over the spillway. While none of this water is consumed or changed in chemical structure, the area would be of little value for recreation if the water were not available.

25.06 PREDICTED RECREATIONAL USE OF STATE PARKS AND WATER DEMANDS

a. Current attendance (1958) records show estimates of:

40,000	visitors to Brandywine Springs
2,124	visitors to Fort Delaware
150,000	visitors to Trap Pond
192,124	estimated 1958 state park attendance

b. Predicted attendance when fully developed

100,000	annual visitors at Branywine Springs
50,000	annual visitors at Fort Delaware
450,000	annual visitors at Trap Pond (maximum development)
600,000	annual state park attendance

Total estimated attendance at the three areas administered by the State Park Commission for 1958 amounted to 192,124 persons; this amounts to 42 percent of our state population. Comparable statistics from other states show California State Park attendance as three times the state population; New York, two times the population; and Maryland State Park attendance equal to the state population. These figures are typical of a national trend showing a greater state park attendance each year for the previous ten years and still increasing. From these figures it would seem reasonably accurate to assume that Delaware's State Parks when fully developed could draw an average yearly attendance ranging from a number equal to the state population to three times that figure, plus an additional allowance for out-of-state visitors.

25.07 HUMAN FACTORS AFFECTING PARKS AND RECREATIONAL WATER

a. Shorter work-week. The shorter work-week and work-day have already been realized to some degree. Mass production, a highly specialized society, and, more recently, automation have already affected patterns of the American family and/or individual.[10]

(1) The Bureau of Labor Statistics, analyzing the composition of America's working population through 1957, notes:

"Since the increase in the labor force will consist to a large extent of younger workers and adult women among whom part-time work is quite prevalent, the trends in part-time employment (were) projected to assess the effect on total labor input to be expected . . .

"By 1969, there will be 3,500,000 part-time workers out of a total labor force increase of 10,500,000. Young workers will make the heaviest contribution to the part-time labor force.(while continuing school) almost 2 million; women over 35 will provide almost all the rest of part-time labor -- 1.3 million."[11]

The same source credits this increased number of part-time workers with changes in the weekly work hours.

"A rough computation of the effect of this factor alone indicates a reduction of about one-half hour of average weekly hours of work between 1955 and 1965."

(2) A purely local sampling of characteristics in today's living habits was made in Northern Delaware, the heaviest populated area in our state, by the Welfare Council's professional and lay teams.

"Abundant leisure is here for the great majority of our people. Communities have come to realize that what people do in their leisure time is socially important and of great consequence ... The machine, urbanization, population, mobility, and rapid social change account in large measure for the difference in leisure between this century and the last ..."12

(3) Metropolitan Wilmington newspapers have, on various occasions, noted reduced weekly work hours as changes in large local corporations during the past two years.

b. Leisure time. The national trend of more free time during the past decade means "social workers and those concerned with recreation and education ought to join forces with the industrialists and labor leaders to retool their thinking ...

"What effects will more free time have on the family, classroom, community? ... The effect of these changes will be interpreted and focused by those who plan now."[13]

c. Buying power. Coupled with additional hours available for many different age groups, the coming half and full century offer the prospect of increased personal income.

The Economic Base Survey for this state report anticipates a $4,300 per capita personal income by 1980 in New Castle County, and $2,700 for both Kent and Sussex. These represent tremendous anticipated increases over 1958 statistics.

d. Mobility. In 1900 when steam and electric railways were the chief forms of transportation, the average traveler covered about 500 miles a year. Today with the airplane and the family automobile, the yearly average has risen to about 5,000 miles. Although part of this growth represents a great increase in community travel, there still is a large gain in leisure travel. The major ingredients, then, of a shifting life pattern already apparent in Delaware, are capsuled with more leisure hours, more buying power, increased population and greater mobility. Each and all have tremendous portent for Delaware's recreational development.

25.08 SUMMARY

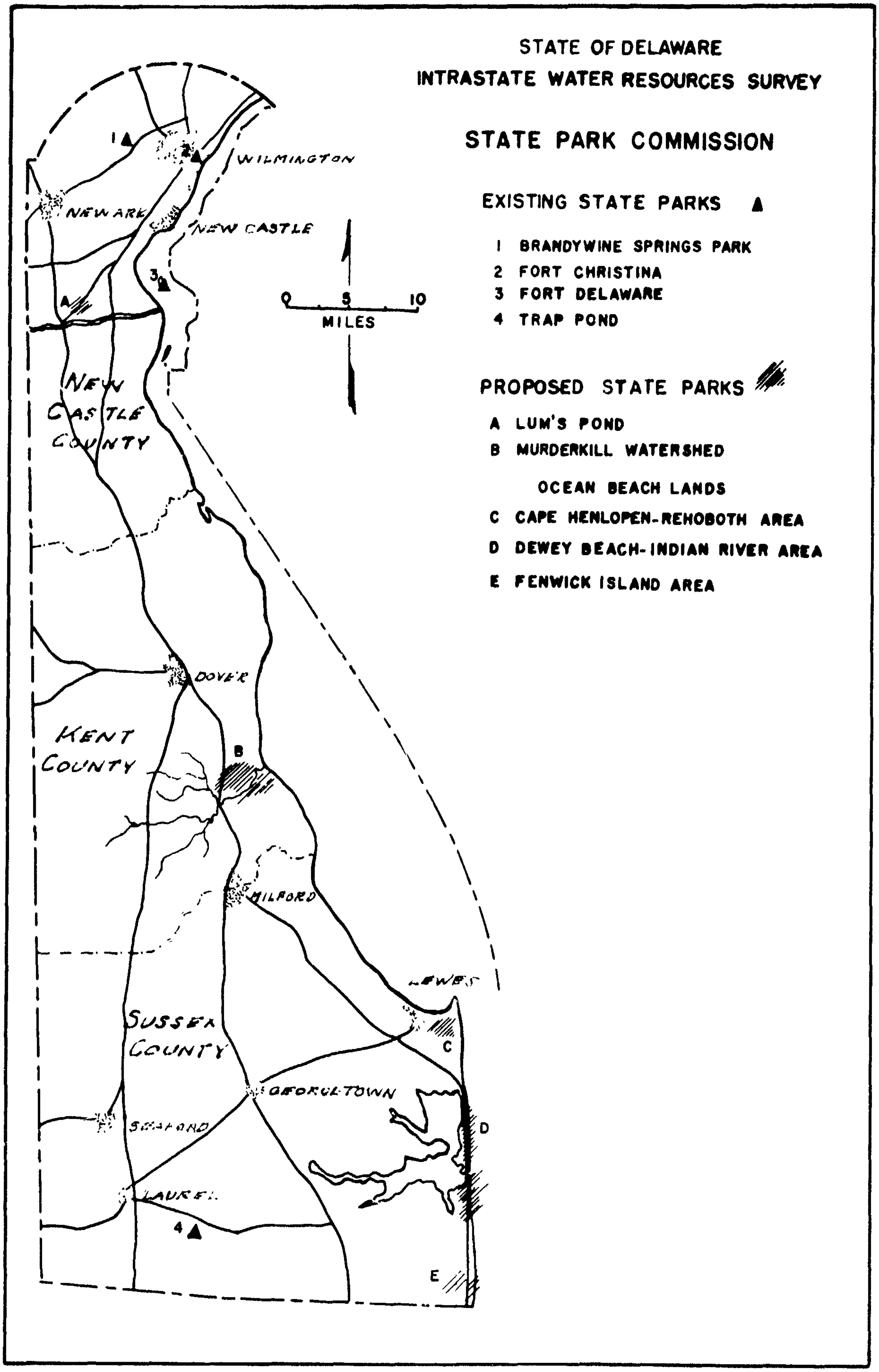
Anticipated use by an increasing population will necessitate purely recreational use of all inland waters now available on lands worthy of state park development in Delaware.

It is estimated that 14,260 acres of state park land in the year 2010, and 33,520 in the year 2060, will be needed to accommodate Delaware's predicted population.

All water and land-need requirements, as given in the text, are minimum estimates.

Waters of the Delaware River and Bay, although an outstanding resource to shell fisheries, commercial and sport fisheries, are limited in potential for other forms of recreation; insects and the murky condition of the water are not conducive to good bathing.

Without increased water supplies and maximum use and conservation of what is now available, Delaware cannot hope to fulfill its recreational obligations to its citizens, much less the commercially beneficial use by nonresident visitors.


STATE OF DELAWARE
INTRASTATE WATER RESOURCES SURVEY
STATE PARK COMMISSION
EXISTING STATE PARKS ▲
1 BRANDYWINE SPRINGS PARK
2 FORT CHRISTINA
3 FORT DELAWARE
4 TRAP POND
PROPOSED STATE PARKS
A LUM'S POND
B MURDERKILL WATERSHED
OCEAN BEACH LANDS
C CAPE HENLOPEN-REHOBOTH AREA
D DEWEY BEACH-INDIAN RIVER AREA
E FENWICK ISLAND AREA
0 5 10
MILES
WILMINGTON
NEWARK
NEW CASTLE
NEW CASTLE COUNTY
DOVER
KENT COUNTY
MILFORD
LEWES
SUSSEX COUNTY
GEORGETOWN
SEAFORD
LAUREL

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3. Report of the National Conference on State Parks, Kenneth R. Cougill, Chairman, (pages 7 and 8), Washington 5, D.C.; December 1954

4. Delaware Code (Annotated) 1953; Volume 3, Title 7, Chapter 47

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7. "Nonurban Recreation Plan in Delaware", prepared by the National Park Service, U.S. Dept of Interior, Region 5 Office, Philadelphia, Pa.; January 1958

8. Delaware State Board of Health, Bureau of Vital Statistics

9. "Development of Parks and Recreation for Delaware," statement by Robert Wheelwright, park planning specialist, to State Park Commission; 1957.

10. "Recreation," Magazine of the National Recreation Association, New York, N. Y.; October 1958 (page 69).

11. Monthly Labor Review, U.S. Department of Labor, Bureau of Labor Statistics, December 1957, Washington, D.C. (pages 1448-1449).

12. Reference 2, pages 41 and 42.

13. Reference 10, page 269.

SECTION XXVI

PROJECTED WATER NEEDS FOR THE STATE OF DELAWARE

26-01. GENERAL

Present water use data and projected needs for the years 2010 and 2060 are considered a primary part of the intrastate report. The basis for the projections is taken from extensive information accumulated by the various departments and/or interests of the State of Delaware. This section presents a summary coordinated review of this accumulated information.

The State Coordinators wish to acknowledge the specific participation and cooperation for this section from the following sources:

(1) Department of Agriculture, University of Delaware, with respect to irrigation.

(2) Department of Civil Engineering, University of Delaware, for surface water evaluation.

(3) Delaware Geological Survey, University of Delaware, for its ground-water evaluation.

(4) State Board of Health, for its municipal water tabulations.

(5) The Highway Department, and many other participants for its projected land use estimates.

(6) The Water Pollution Commission, for its ground-water quality evaluation and industrial water inventory.

(7) State Coordinators and the Statistician, of the State Board of Health, for population, etc., projections for each County.

(8) Various major industrial groups for their invaluable assistance with respect to projected industrial needs.

26-02. FACTORS AFFECTING PROJECTED WATER NEEDS

Surface water sources lie in the extreme northern portion of the State of Delaware and, in contrast, our major ground-water sources are located in the southern portion of the State of Delaware. The following analyses are pertinent to surface and ground-water availability:

a. Surface Sources. Detailed analyses of dam sites considered for the Brandywine, White Clay, and Christina watersheds.

originally proposed by the Corps of Engineers, represented an extensive degree of development. At the pool elevation noted, the combined (Brandywine, Christina, White Clay) minimum range of development would provide a safe yield for a 25-year occurrence interval of 272 mgd. Similarly, the combined maximum range of development would provide a safe yield for a 25-year occurrence interval of 402 mgd, which has recently been concluded as uneconomical. The Corps of Engineers has subsequently removed the Brandywine Pool from their listings; however, it seems appropriate to consider the maximum available because if no other source is available, the pool may become economical. Several considerations must be resolved before any estimate can be made of what portion of these sources could be judged safe yield for the State of Delaware. These considerations involve one or more of the following:

(1) Approximately 90 percent of the maximum Brandywine Pool would, of necessity, be in Pennsylvania. Diversions for out-of-basin use are highly probable and, consequently, the safe yield undoubtedly would be reduced.

(2) Irrigation trends and experience, if practiced to any reasonable extent, indicate that this safe yield could be materially affected.

(3) The proposed maximum Brandywine dam site in Pennsylvania involves approximately 85 percent control of its waters. This should be compared to the very extensive water development of Gun Powder Creek by the City of Baltimore, constituting 56 percent control. It is possible such implied extensive development may not be feasible.

b. Ground Water. Ground-water safe yield in the State of Delaware has been estimated at 418 mgd. Of this total, 400 mgd or 95 percent lies in the Pleistocene sands located in the southern half of Kent County and in Sussex County. A few pertinent considerations appear appropriate in conjunction with ground-water availability estimates, namely:

(1) Ability of ground-water recharges are complex and not too well known. Recharge could be greater than the estimates now used; however, the reverse can be equally true.

(2) There is experienced evidence of saline intrusion in the lower counties as high chlorides have been found in untapped aquifers.

(3) Ground-water quality dictates treatment, in certain areas, before universal use could be made. Extensive analysis indicates that waters from the Pleistocene sands are invariably very acid (low pH) and extremely high in iron.

c. Projected Use. In order to provide a basis for projected water use, there must be adequate data on present use.

Present use tabulations were compiled from:

(1) A complete inventory of industrial water use.

(2) A complete inventory of irrigation.

(3) A complete inventory of municipal water use.

For the purpose of water supply and good water works practice, the 30-day maximum use was applied throughout, except where noted.

With respect to projected needs presented below, it is important to note that tabulations are presented in which industrial cooling waters and steam generation sources from surface streams are both included and deleted from the present use totals. Separate tables are presented for each. A major portion of these waters is brackish; however, approximately 15 percent is taken from fresh water streams. Projected water-needs presentations, therefore, may or may not include the needs for industrial cooling and steam generation.

An estimate of land availability had to be resolved before irrigation use projections could be made. These estimates are presented in separate tables below. The rate of irrigation water use is approximately 15 percent less than that projected by the U.S.D.A. thinking. However, until more final evaluations can be made, this conservative figure has been used.

Water use with respect to irrigation is projected on a 60-day maximum basis since this is the potential period during which water will be supplied. If expressed as a 30-day maximum, the figures would be greater.

Present domestic consumption (30-day maximum) in Delaware averages 100 gallons per capita per day (gpcd). Until further study a conservative 125 gpcd was used for the year 2010 and 150 gpcd for the year 2060. Present thinking and past records clearly show the domestic water requirements have increased at a much more rapid rate.

Due to time limitations, means of obtaining projected needs with respect to industrial water users were given detailed consideration with respect to projected needs. A conservative average increase of 5 percent per year was applied to the remaining industries.

The Coordinators have endeavored to project the needs for the year 2060 simply because they are cognizant that this period is quite pertinent to the overall problem.

Basis for projected needs came from the present water use inventory in the State of Delaware, as of 1957, which was presented in Chapter 18, pages 26, 27, and 28. These tables give a summary of industrial, municipal, and irrigation water usage separated into surface-

and ground- sources whenever feasible. Primary consideration with respect to projected needs was assigned to the domestic, irrigation, and industrial requirements.

The domestic water phase in the present use tables is purely domestic use since industrial use was deleted from municipal inventories. In this way a true picture of the domestic use was achieved. As pointed out previously, a conservative 125 gpcd was used for the year 2010 and 150 gpcd for the year 2060.

26-03. PROJECTED LAND USE

In order to provide a means of estimating the irrigation requirements in the years 2010 and 2060, considerable detail of future land use had to be resolved. The State Soil Conservation Commission must be given credit for a very realistic approach in providing information with respect to future irrigation needs. This organization indicated that they felt they could not compete on a priority basis with land use for incorporated areas, housing and subdivisions, industrial sites, government land, and highways. They further indicated that they could compete on a priority basis with all other land uses. Consequently, it had been requested of the Coordinating Committee to make a detailed survey of the State's lands and determine the number of square miles that would be consumed under the present growth projections of the five prior uses indicated above. This detailed analysis was performed by the coordinators, and the results are presented in Table I. A summary of these various land requirements for the years 2010 and 2060 is presented in Table II. It may be noted from Table II that the minimum available land in Kent and Sussex counties, constituting a total of 1,121 sq miles, was originally considered available for farm use. However, of this total 621,000 acres, according to the Soil Conservation Service (see Chapter 17), is irrigable. Assuming all this land was available for farming and irrigation, the total water needs in the year 2060, projected on the basis of an application of 7 inches per acre, would amount to 1,735 mgd (60 irrigating days). However, for the year 2010 the Department of Agriculture indicated that only 35 percent of this total needs or 607 mgd will be needed.

26-04. PROJECTED TOTAL DOMESTIC USE

In Table III are listed, by county, the present use and projected needs for domestic water in the State of Delaware. It may be noted that this projection is based on a 30-day maximum which results in an average 3.81 times increase in 50 years in the domestic need to 178 mgd.

26-05. PROJECTED TOTAL INDUSTRIAL USE

A summary to the present use and projected needs for industrial requirements in the State of Delaware is presented in Table IV. The values in this table include cooling water which is taken either from fresh water streams or brackish sources. The comparatively large

increase for the years 2010 and 2060 is attributable to large industrial cooling requirements, namely, those of petroleum refineries and steam generation plants. Wherever feasible, the separation of the ground- and surface-sources was noted in the tabulation.

26-06. PROJECTED TOTAL WATER USE

A total summary of industrial, municipal, and irrigation needs projected for the years 2010 and 2060 is presented in Table V. It should again be noted that the industrial projections include cooling water needs, and the irrigation requirements are based upon the 60-day maximum rates. This is a composite of Tables II, III, and IV.

26-07. PROJECTED TOTAL WATER USE EXCLUDING INDUSTRIAL COOLING

A more significant presentation is the Summary Water Use and Projected Needs, Excluding Cooling and Steam Generation, for the State of Delaware as shown in Table VI. This summary is more significant since it provides the actual fresh water supply needs for the State of Delaware. If we were to assume that the entire minimum development of 270 mgd, referred to previously on page 2, could be assured for the State of Delaware, we would have less than half the water required for New Castle County alone in the year 2010, and considerably less for the year 2060. The ground-water sources in New Castle County are comparatively minor.

Our projected needs for the year 2010, excluding industrial, cooling and steam generation requirements, total approximately 1400 mgd. If all surface and ground water, as indicated previously, were readily available for the State of Delaware, we would still receive less than half of our requirements for the year 2010. The only fresh water available to the State of Delaware is the Delaware River. The above estimates were carefully considered; however, we feel they are conservative for the various reasons outlined. More finite evaluations of basic projection rates may result in greater estimates.

The three discussed potential dam sites in northern Delaware are the White Clay, Christina, and Brandywine sites. Originally, the suggested dam sites on the Christina would have provided a reservoir 100 percent in the State of Delaware at either the minimum or maximum pool elevation; and on the White Clay, at minimum pool elevation, 49.8 percent. On the Brandywine, by selecting a site which is quite far downstream and within Delaware, the total area of the reservoir at minimum elevation would be 11.35 percent in Delaware, and at maximum elevation 8.82 percent in Delaware. The above details are presented in Table VII. These facts are significant in that they emphasize the lack of actual land area in Delaware for water storage.

It was referred to previously that the minimum pool elevation for these three dam sites would provide a safe yield for a 25-year occurrence interval of 270 mgd. Further, the combined maximum range

of development would provide a safe yield for a 25-year recurrence interval of 402 mgd. It has been pointed out by the Corps of Engineers that the specific Brandywine site which provides the greatest potential for the State of Delaware is not an economical location. Consequently, it is still unknown how much the estimated development would be reduced; however, the outlook for the State of Delaware becomes even more critical.

New Castle County's projected needs for fresh water in 2010, excluding industrial cooling and steam generation, is 567 mgd. Since the original potential of 272 mgd is faced with the certainty of being considerably less, Delaware is confronted with a need exceeding 300 mgd of fresh water in New Castle County alone, and it would not appear too extreme if this value reached or exceeded 350 mgd.

TABLE I -- PROJECTED LAND USE FOR RESIDENTIAL, INDUSTRIAL, HIGHWAY, GOVERNMENT AND CIVIC NEEDS

	Incorporated Areas, Sq Miles			Sub-Division, Sq Miles		
County	1958	2010	2060	1958	2010	2060
N.C.	23.65	23.65	23.65	21.73	94.60	185.0
Kent	9.61	9.61	9.61	4.77	42.70	103.50
Sussex	16.85	16.85	16.85	4.57	34.40	78.40
TOTAL	50.11	50.11	50.11	31.07	171.70	366.90

	Industrial, Sq Miles			Govt. and Civic			Highway		
County	1958	2010	2060	1958	2010	2060	1958	2010	2060
N.C.	24.64	72.0	176.00	16.32	17.00	17.00	10.81	20.00	30.00
Kent	0.65	21.90	49.30	34.49	38.00	38.00	12.43	18.00	25.00
Sussex	2.17	19.20	37.96	19.00	19.00	19.00	21.79	30.00	35.00
TOTAL	27.46	113.10	263.26	72.81	74.00	74.00	45.03	68.00	90.00

TABLE II

SUMMARY OF LAND USE FOR MUNICIPAL INCORPORATIONS; SUB-DIVISIONS; INDUSTRIAL; GOV'T & CIVIC AND HIGHWAYS, SQ MILES

County	1958	2010	2060	Sq. Miles in County	Potential Cropland in 2060
N. Castle	97.15	227.25	431.65	433	0
Kent	64.95	130.21	225.41	592	367
Sussex	64.38	119.45	187.21	941	754
State Total	226.48	476.91	844.27	1966	1121

TABLE III

PRESENT USE AND PROJECTED NEEDS FOR DOMESTIC WATER,MGD

(30-Day Maximum)

County	1958*	2010**	2060***
New Castle	32.80	114.00	337.5
Kent	7.63	34.30	92.4
Sussex	6.34	29.95	73.0
TOTAL	46.77	178.25	502.9

* 30-Day Maximum Urban Average is 100 gpcd, but Assumed Total at 50 gpcd Includes Military Installations.

** 30-Day Maximum Average Estimate in 2010 at 125 gpcd.

*** 30-Day Maximum Average Estimate in 2060 at 150 gpcd.

TABLE IV

SUMMARY OF PRESENT USE AND PROJECTED WATER NEEDS FOR STATE OF DELAWARE

Industrial Water
(30-Day Maximum, mgd)

County	1958*		2010**	2060**
	Ground mgd	Surface mgd	Ground & Surface	Ground & Surface
New Castle	18.92	753.00	13,892	42,488
Kent	23.20	7.31	106.81	373.8
Sussex	30.20	181.00	3340.3	6479.65
TOTAL	72.32	941.31	17,339	49,341

* These Tabulations Represent a 100% Inventory of Water Use.

** Bases for Projections are as Follows:

(1) Largest Potential Industrial Groups with Respect to Water Use were Given Separate and Detail Consideration, namely, Chemical, Petroleum, Steel and Steam Generation.

(2) All Industries not Included Under Conditions of Footnote (a) were assumed, with Respect to Water Needs, to Increase by the Conservative Average of 5% per Year. This Would Constitute a 250% <u>Increase</u> in 50 Years.

TABLE V

TOTAL SUMMARY WATER USE AND PROJECTED NEEDS, MGD
STATE OF DELAWARE

30-Day Maximum

	New Castle			Kent			Sussex		
	1958	2010	2060	1958	2010	2060	1958	2010	2060
Industrial	772	13,872	42,488	30.5	107	373	211	3,340	7,975
Municipal	32.80	114	337	7.63	34	92	6.34	30	73
Irrigation *	24.65	133	0	53.80	187	622	25.35	287	1,113
TOTALS	829.45	14,119	42,825	91.93	328	1,087	242.69	3,657	9,161

* 60-Day Maximum.

TABLE VI

STATE OF DELAWARE SUMMARY
WATER USE & PROJECTED NEEDS
EXCLUDING INDUSTRIAL COOLING & STEAM GENERATION * MGD

(30-Day Maximum)

	New Castle			Kent			Sussex		
	1958	2010	2060	1958	2010	2060	1958	2010	2060
Industrial	71.0	319.9	1262	23.35	81.85	286.35	31.45	112.4	436.3
Municipal	32.8	114	337.5	7.63	34.30	92.40	6.34	29.95	73
Irrigation**	24.65	133.2	0	53.80	187.0	622	25.35	287	1113
TOTAL	128.45	567	1600	84.78	303	1001	63.14	429	1622

* Taken from Surface Streams
** 60-Day Maximum

TABLE VII

AREA OF PROPOSED DAM SITES WITHIN STATE OF DELAWARE

ESTIMATED

	Total Area, sq mi	Area in Del., sq mi	Area in Pa., sq mi	Per Cent of total area in Del.
Brandywine				
Elev. 202 ft.	5.62	0.64	4.98	11.35
Elev. 222 ft.	9.97	0.88	9.09	8.82
White Clay				
Elev. 149 ft.	1.47	0.84	0.63	57.0
Elev. 175 ft.	2.59	1.29	1.30	49.8
Christina				
Elev. 40 ft.	3.74	3.74	None	100.00
Elev. 50 ft.	6.81	6.81	None	100.00

XXVII - STATE FORESTRY DEPARTMENT

27-01. GENERAL

Woodlands, irrespective of their location, or of the relative commercial wood production potential may contribute immeasurably to soil erosion prevention and water absorption, as well as protection, recreation, and aesthetics. It is likewise conceded that woodlands composed largely of hardwood timber species transpire, in the growing season, great quantities of water which eventually falls elsewhere as precipitation. Delaware is the beneficiary of this natural process possibly to a greater degree than woodlands contribute to other areas. The lack of a perfected yardstick for measuring the economic influence forest lands contribute to our collective economy has resulted in a lesser consideration by the public and consequently at Governmental levels.

Arid regions of this country, which from the beginning of human habitation have been deficient in water supply, have come closer than any other area to developing a yardstick of economic water values and a water conservation program to meet the needs. It is not conceivable, however, that such, or any part thereof, could be expected to apply to conditions in Delaware.

27-02. HISTORY

Three hundred years ago there were about one million acres of forest cover in Delaware, of which less than 400 thousand acres are left. The Northeastern Forest Experiment Station recently published a report entitled, "The Timber Resources of Delaware". To quote Mr. Roland H. Ferguson, the author, "Delaware's original forests were one of the key factors in the early economic development of the State. Besides fuel, each farmer's wood lot provided him with cash when planted crops produced insufficient income. Many timber tracts containing black oak were cut solely for the bark, then in great demand for tanning and dyeing. Also, large volumes of white oak were logged for local shipbuilding, or for export to Holland, Sweden, and England. For a hundred years, 1750-1850, many stout ships were built in Delaware.

"Early explorers and colonists were attracted by the rich resources of Delaware timber. In 1660, a Dutch sea captain wrote that the area was ... full of trees, to wit: Oaks, hickory and pines, and another colonial traveler stated that Delaware has the finest oaks for height and thickness that one could ever see. Others reported that from the soils of Delaware sprang mighty oaks rising 60 to 80 feet to the first branch. Yellow-poplar trees were equally tall and clear. Huge beech, chestnut, walnut, hickory, maple, gum sycamore, and ash trees competed for growing space. Pines--straight, slim, and smooth--stood close together, and cypress and white-cedar grew thick in swamps."

27-03. PRESENT COMMERCIAL FOREST-LAND AREA

Mr. Roland H. Ferguson, the writer mentioned above, further reports, "In 1957, the U.S. Forest Service, in cooperation with the Delaware Forestry Department, made a survey of Delaware's forests. The purpose of the survey was to find out how much timber there is in Delaware, how fast it is growing, and how much is being cut. This is information that public agencies need for planning forestry policies and programs, and that private forest industries use in their search for raw materials and in their plans for future operations. In summarizing the findings of this cooperative survey this report describes the State's forest resources in terms of timber products her people can obtain from it today and those they can expect to produce for them tomorrow. Nearly 400,000 forested acres are found within the State. Of Delaware's three counties, Sussex contains two-thirds of the State's timber volume. As the most southerly region, its soils are level and sandy and its forests--mostly southern yellow pines--occupy 42 percent of the county. But in the more densely populated northern counties of New Castle and Kent, forests cover only 21 percent of the land.

TABLE I

County	Forest Areas (Thousands of Acres)
Kent	78
New Castle	61
Sussex	251
Total	391

"Farmers own more than half of the forest land. Wood lots still are an important integral part of the average Delaware farm."

The report on the commercial forest land area in Delaware states that there are 391,000 acres under all ownership. Of this, 9,000 acres are under public control, which included 8,100 acres of State-owned forest land and 900 acres of Federal-owned forest land. The remaining commercial forest-land area is privately owned, of which 215,000 acres are on farms and 167,000 acres are owned by industrial and other interests.

The survey was based on information obtained from aerial photographs and from sample plots examined on the ground. Trained photo-interpreters reviewed the aerial maps of the State and, after the determination of which areas were forest and non-forest, field crews inspected at random enough plots to obtain a specified level of statistical information to complete the report.

27-04. FOREST MANAGEMENT EFFECTS UPON DRAINAGE AND RUNOFF

As the present intrastate report is primarily concerned with

water resources and the conservation of water it is proper to review the effects of forest management on drainage. Good forest management, has as its basic objective the perpetuation, improvement, and highest use of all forest covered lands. This management finds a great many economic blocks in its acceptance and practice by American people long unencumbered by ancestral inhibitions bred and nurtured by a lack of adequate natural resources as is the lot of most people of the Old World.

The lack of applied forest management to our forest inheritance has and will continue to impose many increasingly difficult problems on the economically usable supplies of all natural resources, including water above and below ground.

In the matter of runoff rate in Delaware, research is not likely to find a perceptible difference between the intensively managed and the unmanaged forest area. Nor does it seem logical that much research will be directed toward finding the answer since economic law indicates that in order for the forests of the future to exist in competition with other land uses, intensive forest management will be a necessity, rather than a choice. Watershed management has long recognized and adopted the device of reforestation as a means of solving erosion,siltation, and evaporation problems and can be expected to continue the practice on publicly owned and managed property. Likewise, privately owned property within important water sheds is likely to be encouraged in reforestation and forest management by public rent or other subsidy, both public and industrial. Federal subsidy is currently available under the provisions of United States Public Law 566, commonly referred to as the "Small Watershed Program" provided that the shed may not involve more than 250,000 acres. The basic concept of this law was to subsidize locally sponsored watershed flood prevention and development programs. This concept was amended to include drainage and is the phase currently being used in planning drainage of the upper Nanticoke Basin. Obviously, forest management and reforestation has only a minor role to offer in any drainage program. Despite this basic conflict of objectives, any landowner in this basin can apply for and receive the advice and services of the State of Delaware Frestry's Department Cooperative Forest Management Service in the same manner as forest landowners not involved in United States Public Law 566 basin plans.

27-05. EFFECT OF PHYSICAL AMENDMENTS OF NATURAL DRAINAGE ON FORESTS

Not only should a study include the effects of forests and forest management on drainage, but the effect of management of drainage on forest should be reviewed. Management of drainage involves physical amendments to natural drainage, including the artificial draining of natural surface impoundments and water-saturated soils. The management pattern which is established in Delaware statutes pertains to "Tax Ditches". The effect of present management of drainage on forests may be both detrimental and beneficial depending on the objectives of the individuals concerned. Since the landowner's primary interest in drainage commonly lies in his cleared acres, the effects such drainage may have on his forest-covered land is not generally considered. Individuals

through whose woodl s drainage channels have been dug or old channels reworked are conscious of the loss of a 50 to 100 foot wide strip of woodland, but few of them are cognizant of the aggregate area thus permanently removed from productive use. It is considerable. In porous soils, drainage usually causes existing water-loving vegetation to die out for a considerable distance (150-200 ft.) back from the channel. In time and with encouragement, dry-land types may through natural processes reoccupy the land, but more often the area thus divested of forest growth becomes a honeysuckle-brier wildlife haven and remains so (hence the deed designation "cripple") until there is economic demand for its conversion to more remunerative use.

To acknowledge that drainage is essential to modern agricultural practice in this area, is not necessarily conceding that the present methods of effecting this drainage is the best or most economical that present day science can devise. Overhead irrigation is rapidly assuming a dominant role in agricultural crop production in this area. It would, therefore, deem appropriate to suggest means of concentrating excess water in impoundment basins from which it can be drawn for irrigation as well as feeding surpluses directly to underground aquifers for recharge, rather than drain to tidewater as is the present and planned pattern. Overhead irrigation is recognized as a consuming use of water in that little if any of it, even on the more porous soils, subsequently filters through to underground aquifers.

27-06. REFORESTATION

The justification for reforestation of lands in the Delaware Basin, based on water resource supplementation contributions, would seem to have been clearly demonstrated in areas where it has been employed. The Northeastern Forest Experiment Station had in operation a cooperative pilot watershed research station "Dilldown" in the Pocono Mountains of Pennsylvania, where pertinent data for the area was being collected. It has not been in operation long enough to cover a complete weather cycle, but it can contribute some interesting observations on foliage rainfall interception, transpiration, soil absorption and runoff regulation. Because of local economic determination this station was closed at the end of 1958. It is not conceivable that the data collected there could be applied to all conditions in the Delaware Valley, but it is sufficient to indicate the effects of forest cover on water resources. Naturally, there can be no constant factor in a multivaried relation under study, nor is it likely that fundamental research of this type can contribute information of immediate practical use on other areas with dissimilar characteristics. We do know that the root mass and duff on a forest floor forms a continuous spongy layer that protects the porosity of the underlying soil; that the water absorbing capacity of this layer is variable and that when it becomes completely saturated the surplus can trigger floods. Consequently, the greater acreage of this spongy aquifer that is maintained in the basin, the less likelihood there is of devastating flood and drought occurrence.

27-07. INFLUENCE OF DELAWARE STATE FORESTS ON WATER SUPPLY

None of the Delaware State Forests are large enough or so situated as to materially influence surface water supplies used by municipalities or industries within the State. It is felt that as presently constituted and managed in addition to their serving their prescribed purpose, forests do contribute to underground water reserves and naturally to runoff retardation and transpiration, to no greater or less degree than unmanaged private forested areas.

However, the Edgar M. Hoopes Reservoir of the Wilmington Water Department is a living example of foresight in planning to meet municipal water demands. This reservoir has been protected from excessive siltation and minimum evapotranspiration losses secured through the medium of reforestation of its adjacent slopes with conifers, but funds have not been provided for the complete acquisition or control of the basin that feeds this Wilmington reserve supply.

It is felt that any municipality in Delaware, or for that matter in the Delaware Basin, should explore carefully the possibilities of acquiring without undue delay control of basins that do or could, within economic limits, contribute to their present or prospective domestic water needs. Admittedly, such media are but stopgaps to the solution of the overall water resource problems which have been created for the present and the future, and there must be regulatory measures adopted for the wise use of the available water supplies as well as improvement in quality, quantity, and stability of source. However, it is not incumbent upon the private landowner that he manage his lands to contribute indirect benefits to others at his expense without proper compensation being made to him for this product of his effort.

27-08. THE FUTURE OF DELAWARE'S FORESTS

The recently completed Timber Resources Review of the U.S. Forest Service, reports facts and predictions on the Nation's timber resource as distinct from forests as a natural resource. The Nation is alerted to the situation which confronts the people and this report makes broad recommendations on what can be done to meet anticipated future timber needs. It predicts that to meet timber demands in the year 2000 our national annual timber growth, now standing at 47 billion board feet, must approximate 90 billion board feet or more. The year 2000 is only 41 years away. Doubling the saw timber production of the forests, in the face of the progressive depletion of existing forests and the conversion of such lands to other uses all within less time than it takes to mature to sawlog size, the fastest growing timber tree (loblolly pine), will take a tremendous effort by every owner of forest land whether publicly or privately owned.

This same report points out that three-fourths of the productive timber lands of this Country are a part of farms and that in consequence the key to our future timber supply is in the hands of those who own

these small forests.

This is precisely the situation existing in Delaware where only 9,000 acres of forest land is under public control, and not all of that by any means under intensive management.

The State Forestry Department has been asked to estimate the probable extent or acreage of forest cover in Delaware 50 and 100 years hence. The simple fact that 300 years ago there were about one million acres so covered, and that there are now less than 400,000 acres left, contributes little when it is realized that it takes 25 to 100 years to mature a forest crop and that 99 percent of all Delaware forest lands are privately owned in small individual holdings whose owners cannot afford to own, pay taxes on and manage such a long term crop in the face of ever increasing land-use pressures accompanied by rising land values. It is, therefore, obvious that economics will determine how much land stays in forest cover.

27-09. **COMMENTS**

Thus far the interim survey reports coming to the attention of the Department appear to deal with basin water quality, use regulation, water distribution, and proposed impoundment facilities. It is hoped that in these several treatments, serious consideration will be given to the potential contribution forests, can and do, make to water resource conservation and moisture generation.

The Department begs recognition by the Corps of Engineers of the concept that forest cover can and does influence climate, and by such influence contributes to increased precipitation, inhibits flash runoff, improves infiltration rates of most soils, impedes both wind and water erosion rates, regulates stream flow, and generally contributes such a multitude of benefits to civilization that they are accepted as normal and elicit with no conscious response from the man on the street. Very few research people are permitted to examine the broad scope of natural water generation, but fortunes may be spent in the search for an artificial device to solve critical water resource problems.

Herbert C. Storey, Director of the Division of Watershed Management Research of the U.S. Forest Service, puts it rather succinctly thus, "The type and amount of (forest) influence will depend upon the type and conditions of the forest. And it should be further emphasized that some characteristic desirable from the standpoint of reducing flood flows may not be compatible with maximum water yield objectives." Mr Storey further points out that "maximum flood control calls for the retention and dissipation of water in the watershed, whereas, maximum water yield requires the reduction of evapotranspiration losses".

Delaware's assets outrank its size. Its rich, generally rock-free soils, its moderate climate, adequate precipitation, and generally level terrain have contributed immeasurably to its agrarian foundation

and growth. However, these same qualities did not escape recognition and evaluation by industry, which in any extensive expansion or relocation, is accompanied by urban and suburban residential expansion that generally is a larger consumer of land than the industry that triggered it. Such consumption of land is rarely, if ever, the product of methodical planning at any level of Government in this Nation, or in any Country whose land-use policy is founded on private ownership of this basic resource. Regardless of how one locks upon the American land-use policy, when it is analyzed critically from the standpoint of many of our natural resources, specifically water and forests, it becomes quite evident that in the process of development and exploitation of these resources that problems have been created not only for present people-. but for generations of unborn citizens. As the popuiation expands, ,o will the demands increase for further exploitation of these resources, many of which are not of a replenishable nature, at least not by any presently known or economically feasible method. Fortunately, forests, and to some extent water, are resources that do not fall into this category. Forests are replenishable both by natural and artificial means provided other essential elements of plant life are adequately available. However, in areas where land-use is subject to uncontrollable factors of change, forest survey data is likely to become obsolete and unreliable quickly. This appears to be the situation in Delaware.

SECTION XXVIII

LEGAL ASPECTS

28.01 GENERAL

For any extensive water supply plan to succeed in Delaware many legal problems must be resolved not only within the State but also with the Federal Government and the adjoining States. Nature, in furnishing this resource to man, does not recognize man-made boundaries of the States or portions thereof. If every individual in the Delaware drainage basin is to have an equitable share of the benefits to be derived from the supply, future legislation must recognize the water needs of all, the intricate pattern of our civilization, and, above all, the terrain of the basin and the physical laws of nature. Unless man causes some drastic change to divert water from the basin, the river will flow from its source to the sea, ofttimes supplying little water and on other occasions releasing such quantities as to flood the areas through which it passes. However, nature is generous only to a certain limit, that limit being reached when the demands of man equal that which nature can supply in its natural environment.

In many locations along the river and its tributaries the demand has exceeded the supply and in other locations man has spoiled the quality of the water so that corrective measures have had to be taken locally to husband the water. The population of our civilization has expanded to such a degree that water can not be obtained from the immediate drainage basin. There is an example of a governmental unit of one locality being forced to go into another drainage basin for water in order to satisfy its needs for expansion and existence. The Delaware River Basin area has been compared to the Elber-Barmen and Lille-Roubaix districts in Europe which are heavily populated, highly industrialized, and are the backbone of the economy of their localities. The Delaware Valley is expanding at such a rapid rate that urban areas, formerly distinct as political units and as topographic features, are growing and flowing together to form new configurations of densely populated masses which must be recognized and which are extending beyond man-made boundary lines.

Section VII, entitled, "State Coordination Organization," explains the assignment outline in which various queries were posed; those involving the legal phases are stated on page 7-8.

28.02 REVIEW OF STATE LAWS

The State Coordinators sought advice from the office of the State Attorney General. On November 12, 1958, a conference was held with the Chief Deputy Attorney General, discussing with him the foreseeable problems of the water question. Below are excerpts from a letter from the Chief Deputy Attorney General with editorial comment to provide continuity.

"In our conference on November 12, 1958, we discussed the 19 questions asked of the Attorney General ... ."

"At that time, I pointed out the tremendous difficulties involved in answering such questions without respect to specific fact situations or statutes. You (Dr. Kaplovsky) and Mr. Simpson indicated your awareness that it is simply impossible, for instance, to review the legal factors concerning riparian rights, soil conservation, land management, ground water, sediment discharge, and so forth. Although the Attorney General's manpower resources are extremely limited, it is not this alone which restricts any definite answer but the nature of the problems involved. With unlimited manpower at our disposal, this Office still would be unable to give any definitive answers to your problems. However, as I noted at the time, the common law and equity practice is founded upon private litigation by individuals able to show a present or prospective damage to them or their property which is compensable to them in money or preventable by injunction. This is the underlying requirement behind the discussion of riparian right contained in Bulletin No. 314 (Technical), November, 1955, by the University of Delaware Agricultural Experiment Station. The courts do not recognize any interest in governments or agencies to provide for beneficial use of land other than pursuant to legislation.

"I understand that you are interested in the governmental powers available to an agency in Delaware seeking to provide for the present beneficial use of water resources and present and future powers to act to preserve water supplies. Therefore, I can only indicate that, where one finds no statutory authority for you to act, it must be presumed that there is no authority to act."

The Attorney General's Office could find no authority competent to act in the public interest in the following areas: The development of storage and sale of water, the development and sale of hydroelectric power, sediment discharge controlled by man practices upstream, flood plain zoning, flood warning coordination, riparian rights on small streams, ground water and land titles, to handle financial operations, to handle land acquisition and disposal, to handle construction, to handle operation and maintenance, to handle licensing, or to handle water resources in any way.

With regard to the matter of pollution and contaminant control, "Your question No. 5 concerning pollution and other contaminant control is fully and competently covered by you on pages 31-33 of your tentative draft of the Delaware Water Resources Survey.

With regard to the matter of land management and use, "Your question No. 9 concerns land management and use. In answer to this question, it may be noted that the Levy Court of New Castle County, pursuant to 9 Del. C. 2601, has certain powers to control use of land for, among other things, water supply conservation and soil conservation. I can find no authority with similar powers in the other counties."

Regarding the matter of Soil Conservation, "In respect to your question No. 10 concerning soil conservation, I refer to 9 Del. C. 2601, noted above, and again I can find no other authority with power to control and enforce soil conservation."

Information was also sought on State water laws and policies, "You ask, in question No. 2, about present State water laws and policies. The only statutes establishing governmental control are the previously mentioned Water Pollution Control Commission, 23 Del. C. 701-712, and the New Castle County Levy Court zoning power. Senate Bill No. 98, providing for a Water Resources Commission, has, as you observed, not yet been enacted."

As to present Federal water policies, "With reference to your first question concerning present Federal water policies, this Office is unable to make any analysis which would be of use to you in your work."

In view of the above evaluation of the legal aspects it appears quite evident that the State of Delaware is in dire need of legislation to permit effective participation with other governmental entities and construct facilities with regard to its future water needs.

SECTION XXIX - DISCUSSION

29-01. GENERAL

It would be well to sharply focus upon the more pertinent problems and needs related to water resources development. Further, it must be concluded that a change from the past methods used for water resources planning in the Delaware River Basin is in the offing. In addition to the responsibility of projecting the needs for the year 2010, there is involved the solution of many knotty problems.

When the plan for preparing a water resources survey for 50 and 100 years hence was adopted, the immediate effect was to make the shorter-term planning of 15 and 20 years obsolete. Certainly, structures or parts of the overall plan could or should be undertaken in 15 and 20-year segments. However, it would be completely unacceptable to plan for only 15 and 20 years and assume that an additional 20 - or 25-year period plan would follow immediately thereafter, and the various problems related to this development would remain parallel and/or consecutive. Delawareans are fully cognizant of the fact that if the immediate plans should provide facilities to satisfy a localized need, it would become increasingly more difficult for the satisfied segment to participate in the planning, needs, and problems of the remainder. Consequently, a partial approach to this staggering problem is far less desirable than no plan at all.

29-02. PROJECTED GROWTH

The Office of Business Economics has undertaken and completed the task of projecting the growth and development which they believe, as an average, will take place in the Delaware Valley 50 years hence. It is assumed the OBE has provided the best overall development projection which is possible in this basin area. We must, therefore, take the position that for all planning purposes this rate of growth will become fact and the problems related thereto, will take place concurrently with the growth change.

The OBE has indicated that the average growth within the Delaware Valley would increase by 2.5 times by the year 2010 and for parts of Delaware the change would be slightly in excess of threefold. Consequently, projected water needs for domestic, industrial, and irrigation uses must be increased accordingly. Further, in order to provide a valid water need estimate for the year 2010 by applying the rate of growth as indicated by the OBE, a very careful present water-use study, of necessity, became paramount.

A 100% inventory of domestic, industrial, and irrigation water-use was made for Delaware. There are non-consumptive users other than irrigation and industrial cooling, such as recreation, navigation, and pollution requirements. However, these are more related to quality than to quantity. Further, it was deemed important to evaluate the

water supply whether the source be from surface, ground, or salt water, to meet the needs.

29-03. WATER USE ESTIMATES

a. Domestic. The domestic water requirements, associated with this growth and development, are not difficult to resolve. Delaware has assumed for the year 2010 that the domestic consumption would reach 125 gallons per capita per day (gpcd) and for the year 2060 it would approximate 150 gpcd. It is considered that this rate is conservative. However, the domestic use of water will be a comparatively small percent of the State's total water requirements for industry and irrigation use. Consequently, even though domestic water requirements take a high priority, the comparative amounts involved are small and rather exact, and consequently, less emphasis is placed on this phase.

b. Industrial. Delaware's estimate of fresh water requirements for its industries is considered quite conservative also. Even though the OBE has indicated an excess of threefold growth within the State, our projected needs do not show an average threefold increase in the year 2010. In fact, for industries without specific growth information, we assumed a 5% increase per year or 2.5 times in the 50-year period. However, for industries having sufficient growth information, projections were made accordingly. The maximum, in the latter instance, totaled 5% per year or threefold in the 50-year period. This may be compared to projections in the report, "Forecast for Petroleum Chemical", (1) which projects the forecast for petroleum chemicals to the year 1975. This summary-type report covered the period from 1955 to 1975 in 5-year intervals. It may be observed that the estimated increase of petrochemicals in the 20-year period between 1955 and 1975 is 2.63 times. This may be taken as an indication of progressive development, and, for a 50-year period, through the year 2010, the increase becomes quite significant in that it varies between 5.8 and 6.5 times. Therefore, the national picture as projected in this article for petroleum chemicals constitutes a projection rate double the highest rate used in Delaware for industrial development in the year 2010. This further emphasizes the conservativeness of the projections made in regard to industrial growth for the State of Delaware.

c. Irrigation. It has been noted that the U.S. Department of Agriculture projected irrigation needs (2) to 2010; however, they assumed that irrigation requirements will continue to increase until 1975, and thereafter will show a declining rate of use. This particular position taken by the USDA is difficult to comprehend. Is it possible that the USDA based their decision upon the assumption that by 1975 all available ground water will have been consumed by irrigation needs? If this be their reasoning, it is in conflict with the OBE approach since they (USDA) are assuming that by 1975 water will be the limiting factor for irrigation and not the availability of irrigable cropland. As stated previously, it must be assumed that the OBE projected growth will take place and if sufficient water is not available

on location, it will be obtained elsewhere. The important point is to provide the estimated needs in accordance with the OBE projection. If each interest is to make its independent projected growth evaluation for the future and by-pass the OBE report, then the Corps of Engineers survey report would have little continuity or meaning with regards to projected needs.

An interesting editorial entitled "Soaring Land Prices" (3) stated, "There are two agricultural predictions for 1959. One is that farm products prices will slip off an average of 5 to 10 percent. The other is that the farm land values will advance 6 percent above the record level of this year.

"These predictions make sense only on the basis of supply and demand. There is not enough demand to absorb the rising total of farm production. And there is not enough farm land to satisfy the demand for it.

"This year's good crops at profitable prices put money into the hands of the larger farm operators who are using it to add to their acres. That comprises the biggest demand for farm land. Then, too, more than a million acres of land per year is diverted to city growth and public improvements.

"It is only a question of time until farm land prices reach the point where pressures begin for a larger supply. There are many millions of acres of land that can be reclaimed through drainage and other means."

The above article expresses sharp disagreement with the projected thinking of the USDA with respect to irrigation needs in the future.

29-04. WATER RECLAMATION AND UTILIZATION

Problems now facing the State of California (4) with respect to water supply can be taken as a warning of what may confront us in the not-too-distant future. An important source of water made available through recovery processes is waste water reclamation and utilization. It is conceivable in the Delaware Valley that the limit to growth and development is not the water available but the ability to discharge the used waters without ill effect. The problem is more critical in the upper reaches of the estuary than it would be in a highly saline reach. Reclamation and utilization of waste water will therefore serve a better purpose, in that it would handle the waste which would not be discharged to streams and would supply additional needs. It is, therefore, pertinent that a few of the conclusions drawn from the investigative work done by the State of California be contained herein.

This report makes the following profound statement: "Waste water constitutes an increasing portion of the national water supply;

the use of this resource derives from the economic practicability. Increasing acceptance will result in further economic need, accompanied by proper planning. Future research will be required to overcome technical problems and to reduce costs."

California's reclamation investigation (4) has come up with the following summary type conclusions:

(1) "It is possible for a group of private farmers to organize, finance and construct a reclamation system to utilize a sewage effluent for economical irrigation of field crops, within the requirements of State and local authorities."

(2) "It is necessary to make a careful segregation of industrial wastes from the domestic sewage in order to maintain irrigation water quality."

(3) " An opportunity exists to obtain further data on the effect on crops of irrigation with primary effluent and to evaluate operating problems directly related to public health acceptance."

(4) "The problems peculiar to irrigation with reclaimed water such as odors, corrosion, chlorination for coliform control, and soil salinity can be controlled by careful planning."

(5) "The irrigation of golf courses provides an ideal use for reclaimed water, and increasing public acceptance indicates the need for early establishment of reasonable public health standards."

(6) "Experiments on recharge operations have shown that reclamation of waste water for ground-water recharge through injection wells is possible."

(7) "Coliform organisms are airborne only in moisture droplets; therefore a health hazard may exist within the zone of mist occurring when a non-disinfected waste is being used for spray irrigation."

29-05. RISING SEA LEVEL

In view of the continually-rising sea level, the article (5) which summarizes the work done on the Zuiderzee in Holland becomes of interest. One cannot help but observe that in the lower reaches of the Delaware River area, low-level land reclamation may not be as remote as one may care to believe. In Holland, crops have already been harvested from some 5,000 acres, and 500 acres of a sandy soil have been forested. Approximately 20,000 acres of land will be reclaimed this year from the 133,600-acre Eastern Flevoland section. To do this 20 miles of massive dikes were built between 1924 and 1932 to shut off a major part of the Zuiderzee from the North Sea. Then smaller sections within the Zuiderzee were diked and drained to reclaim land for agricultural purposes.

By properly controlling sluice gates in the dike, saline sea water has been prevented from entering the lake. Sweet river water feeding into the lake is permitted to flow into the North Sea. Each year some of the salinity is washed out of the lake area. Eventually all the salinity will be removed.

Although such need for land recovery is not imminent in Delaware, however (50 and 100 years hence), it would be improper to ignore the possibility of a need for such land recovery procedures.

29-06. LOW OXYGEN WATER FROM IMPOUNDMENTS

"It seems obvious that the trend in water resources development (6) continues to be dams and more dams. We already have 1¼ million farm ponds (in U.S.) averaging two acre-ft storage in addition to 10,000 reservoirs larger than farm ponds. More large and small dams are needed to capture and conserve water. By construction of such dams, some problems are solved and others are created.

"Deoxygenating effects of reservoirs is a problem to sanitary engineers. Storage reservoirs subject to thermal stratification generally have excellent quality water in the upper levels. The lower levels may be of low quality devoid of oxygen. This condition occurs even in the absence of man-made pollution. It is caused by the decomposition of organic matter in lower levels where stratification prevents atmospheric reaeration.

"When water is discharged downstream from the upper levels, there is no problem. However, technological advances in design and operation of dams where power is a factor have permitted the location of penstock intakes at lower levels to the advantage of power production. This had permitted the release of low quality water. In effect, modern power dams have tended to release polluted water. Dissipation of dissolved oxygen is an important factor as damage to fish life is involved. Downstream communities and industries also are damaged in that less oxygen is available for pollution control purposes.

"Paradoxically, the discharge of extra volumes of water could add to the number of pounds of dissolved oxygen available for downstream pollution assimilation purposes but in terms of dissolved oxygen concentration, the released water may be unacceptable to the State Water Pollution Control agency. Furthermore, the discharge of larger volumes of water increases the depth of stream flow which reduces the rate at which reaeration takes place. Thus, the rate of stream self-purification is slowed when more water is discharged in this case.

"The answer to the low dissolved oxygen problem of impoundments lies in raising the dissolved oxygen concentration in water available at lower level penstocks. To accomplish this will require an upsetting of physical, chemical, and biological natural balances. Further, complex problems can be anticipated if the primary problem is solved.

"Irrigation impoundments and diversions are of particular interest and concern to the sanitary engineer. Agriculture Handbook No. 60 states: There is a tendency to divert for irrigation all of the available water. This means that over a period of years the downstream diversions may change from uncontaminated river water to a substantial proportion of drainage return flow of poor quality. There is frequently less water, and water of lower quality available for reuse by all concerned. In most situations a water unsuitable for further irrigation is unsuitable as a public and industrial water supply source.

"As state and interstate water pollution control agencies accelerate enforcement programs, sanitary engineers seek disposal areas other than streams and lakes. In difficult situations, the tendency is to look toward ocean disposal, lower level subsurface injection, and use of the soil where such methods are feasible."

29-07. FLOOD CONTROL

In a recent Tennessee Valley Authority report (7) a series of interesting remarks were made on the national flood damage potential. This organization made the following observations: "The historical approach to the reduction of flood damage has been to construct protective works--dams, reservoirs, and levees--with little or no attention to preventive measures. In the past 20 years the Federal Government has been responsible for construction and financing most of these projects. Although they protect existing developments, the total flood damage potential of the nation continues to grow each year. It would be uneconomical to protect all newly-developed areas, and at present rates of construction, it could never be accomplished. A new approach is needed.

"To implement this program the following recommendations are submitted for consideration by the Executive Branch, the Congress, and the States:

(1) A national flood damage prevention policy should be developed. The objectives of the policy should be (a) to prevent the unnecessary spread of buildings and other improvements to new flood hazard areas, combined with continued efforts to alleviate damages in those flood hazard areas which have already been developed, and (b) to encourage appropriate state and local bodies to assume the responsibility for initiating and developing plans and programs for local flood damage abatement through construction of protective works and establishment of land use controls as necessary. The policy should also provide a basis for technical and financial assistance by Federal agencies.

(2) If protective works are economically justified as part of the local program for flood damage abatement, the Federal financial contribution to such projects should be contingent upon the requirement that the city or state initiate and prepare engineering plans

of the proposed works and that the plans be submitted to an appropriate Federal agency for review and approval.

(3) As a prerequisite for the contribution of Federal funds to local flood protective works, State and local governments should be required to adopt and administer flood plain zoning and other such controls as are needed to prevent the unnecessary spread of buildings and other improvements in areas subject to flood damage

(4) Provision should be made to insure that all Federal agencies having responsibility related to site selection or financing of physical structures observe local flood plain zoning and other standards in carrying out their responsibilities, and in cities without land use controls, but subject to flood damage require establishment of such controls before Federal programs are approved and put into execution.

(5) An expanded and systematic program of collecting and analyzing basic flood information by existing Federal agencies should be authorized which will meet the needs of states, local communities, industries and others in adjusting to flood conditions.

(6) For the purpose of providing cities and communities with basic flood information on which to prepare plans for growth and development and for the prevention of local flood damages, appropriate Federal agencies should be authorized, where such authorization is necessary, to prepare upon request local flood studies which would describe and analyze the local flood situation."

29-08. SALINITY CONTROL

It is not uncommon to find reference made to the relief (8) that augmentation of flow in the Delaware River would do very little to prevent salinity intrusion unless sustained at a comparatively high stage. Numerous experiments (9) have been conducted on the river model to study the salinity front movement (isochlor) during various stages to sustained flow. Unfortunately, the problem is not so easily resolved. These tests could be directed comparable to the prototype if the controlled flow stage level represented the total water released to the river over an extended period of time. It has been shown in prototype investigations that the stage of flow alone on a particular day, week or month may not represent the expected isochlor, but that the salt water to fresh water ratio existing prior to a period of steady flow is a major determining factor of final salinity front position.

It is well known that the higher the spring runoff the farther downstream will be the salinity front. The degree of movement should be qualified as to consider the composite of spring runoff, not the daily, weekly, or even the monthly average flow. If we should experience a wet spring, less sustained or augmented flow would be needed to establish the maximum isochlor permissible, and if we should

have a dry spring, additional control would be needed. However, by withholdir₀ spring flow to fill the augmentation flow reservoir, are we not, in effect, creating a dry spring which, in turn, will require additional augmentation during the late summer and early fall? The all-important question of how much salinity control we are to achieve by comparatively minor augmentation procedures is still unanswered. One cannot disregard the influence of total flow over a segmentized evaluation under prototype considerations.

29-09. SALINE CONVERSION

In an effort to resolve the all-important phase of costs with regard to water from saline conversion, one is continually faced with statements and reports that differ materially. For the past several years considerable effort and money have been expended through the U.S. Department of the Interior for saline conversion research. Reference is made to the potential future cost for saline conversion water that in the not-too-distant future, within the next decade, saline water can be converted to fresh water on a possibly larger scale at approximately 50 cents per 1,000 gallons. This 50 cents per 1,000 gallons is compared occasionally with the present average cost in the United States of 30 cents per 1,000 gallons and in some localities considerably more. Men in the field of water treatment and supply sharply contend that the actual treatment of water is only a small percentage of the total cost of water, and that if one includes the cost of distribution in the price of desalted water per 1,000 gallons, the consumer would be faced with a charge considerably higher than 50 cents per 1,000 gallons. These differences of opinion are clearly shown in several article abstracts summarized below.

Mr. E.H. Aldridge (11), in his reply to a sea-water conversion article printed in the Engineering-News Record (10), stated that the perspective conversion costs are being reduced to some three times the present consumer cost or approximately $1.00 per 1,000 gallons against 30 cents per 1,000 gallons. In answer to this inference, Mr. Aldridge made the following statements: "In 61 private water utilities serving some 3.5 million people in the northeast quadrant of the country, the consumers pay 28.3 cents per 1,000 gallons of water produced in 1956. That was the cost of water delivered to the tap. Since some 75% of the total investment in a water plant is required to pump and distribute the water, a substantial part of the delivered cost is due to this factor.

"Further, a large part of the cost results from such business expenses as reading meters, accounting, billing, collecting, and administration. For a private utility, taxes absorb nearly 20% of total revenue received.

"The actual cost of collecting and processing the water, including return and depreciation of the investment, and the applicable taxes, averages about 10 cents per 1,000 gallons. This is the figure

deemed comparable with the figure mentioned, $1.00 per 1,000 gallons. You don't make it clear whether or not capital costs are included. Certainly, taxes are not.

"Once having solved the legal and political problems involved in the development of our water resources, engineers can spend a lot more money on developing such resources in this country without approaching the cost of converting sea-water, or even high chloride water."

Mr. Raymond J. Faust, Executive Assistant Secretary of the American Water Works Association, also replies (11) to the Engineering-News Record article of March 12 (10) as follows: "Your story titled U.S. Plans Big Sea-Water Distillery could easily give the reader a false impression as to the relative cost of desalted water and water from a public system. You say: Conversion cost in the new plant is expected to run less than $1.00 per 1,000 gallons. This is half the cost of the best operation at present but still three times what most American consumers pay for water.

"Exactly what constitutes conversion cost I can't say - but I assume it to cover only the production of water and the capital cost of the distillation plant. It would not include, for example, high-lift pumping and distribution, but would take the place of treatment costs in a public supply.

"I wish to stress the point that a direct comparison of conversion costs with the cost of water to consumers of public systems is not correct. The latter costs involve many factors such as (1) collection of supply, (2) treatment, (3) pumping, (4) distribution, (5) storage. Of these items distribution is by far more expensive. Usually the capital investment in distribution represents from 70% to 90% of the total invested in the system.

"The AWWA Survey of Water Utility Operation in 1955 shows that for those towns where filtration or softening is involved (major treatment) water rates are 23% higher than where only minor treatment (disinfection) is required. If this percentage is applied to the average cost of water from public supplies (30 cents per 1,000 gallons) it amounts to about seven cents. Thus, the average cost for supply, pumping, distribution, and storage represents 77% of the rate.

"If conversion costs about $1.00 per 1,000 gallons, then the added cost to deliver the water to the consumer would approximate 23 cents, making a total of $1.23. That cost could be compared directly with the 30-cents charge for water from a public system. The ratio between costs, therefore, is 1 to 4 and not 1 to 3 as suggested."

The prediction (12) of the Chief of Saline Water Development in the United States, A.L. Miller, M.D., sums up his agency's program by stating, "Within five years the cheapest new supplies of fresh water southern California will be able to get, will come from the sea."

This is in contrast to recent action taken (13) by the State of California to invest heavily to obtain water from the north for the arid south a distance of approximately 500 miles. Further predictions (12) were that for at least the next decade or so, conversion of salt or brackish water will be economically worthwhile only for regions with very poor or nonexistent supplies. Dr. Miller forecasts, "As the size of plants increases to 15 to 20 million gallons per day, the cost may be expected to drop to about 60 cents per 1,000 gallons."

In the past few years, the cost of producing fresh water has been cut in half. Dr. Miller says, "That in the next 10 years it will be cut in half again. This would bring the cost at the plant down to 50 cents per 1,000 gallons, perhaps less. Most communities are now paying 30 to 40 cents."

This article (12) further states that "Some waterworks engineers quarrel with the cost picture painted by the government (11). They pointed out that 50 cents per 1,000 gallons doesn't include distribution. Dr. Miller countered that cities often don't figure in all their real capital costs in quoting prices at 30 cents. Moreover, where distribution systems are already installed and paid for, the cost does not have to be figured in, he says."

The last statement needs further comment. Whether the price is 30 cents or more for domestic supplies, at present, is not pertinent. The question which is clearly not answered is whether or not the two comparisons, the present costs of fresh water and that of saline conversion water, are being considered on a comparable basis. It appears evident that if the cost of water from both processes were to be compared on similar conditions, the cost for saline converted water would be still considerably higher than the present cost of fresh water. It is, therefore, considered poor judgment to assume a highly optimistic point of view with respect to saline conversion possibilities as a means of supplying fresh water for the State of Delaware in lieu of other fresh water supplies. The comparative costs will be widely different for some period of time to come, and it is also possible that the cost may never become competitive, at least not in the next 50 years.

29-10. OUR INHERENT OBLIGATION TO THE FUTURE

Trite as the expression may seem, this report portrays the handwriting on the wall -- Delaware will suffer in the future due to a water shortage. This will occur unless our people are aroused from the lethargy into which they have fallen due to the bountiful existing supply which meets the needs of the current populace. However, many will disagree with the forecasts made, and rightly so, but let all remember that they themselves are the generators of the future population. The past verifies the fact that unless a disaster of considerable magnitude occurs to interrupt the heretofore geometrical rate of increase, the population will be significantly greater in the not-too-distant future. The immediate past and present populace have legislatively or otherwise created organizational units, governmental and otherwise, to advance the well-being of the populace, to raise the standards of living. and in doing so, served the public good and if necessary protected the individual even against himself.

The advantages to be gained in our State have been publicized throughout the Nation, thus inviting people and industry from other sections of the country to establish in Delaware.

A review of all the reports by the different authors of this document clearly portrays the expectation of a crowded future. We read in current literature many accounts of the exploding population. Each agency is projecting what is needed to satisfy the future population of 2010 and 2060, the majority of which are still to be born. Even those now in their infancy or early childhood will feel the effects of what is forecast in this document.

The past has proven that individuals can accumulate property and personal effects, but the past has also proven that this is subdivided amongst the remainder. For those less fortunate their hope is that their progeny will fare better.

Nature created on the surface of the earth the area known as the Delaware River Drainage Basin long before the colonization of America. Through the course of history, by action of land grants and wars, political subdivision has been effected without regard to the characteristics of the basin. Yet Nature in supplying water does not recognize these subdivisions, and the problems created are those of man.

Our forefathers through common action passed on to us our present government. Today the present population must preserve the resources for those of the future who are still in absentia. Many of us will not be alive to appraise the results of our endeavors, but let us hope that we will choose the right line of reasoning.

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